The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVII No. 8 AUGUST, 1956

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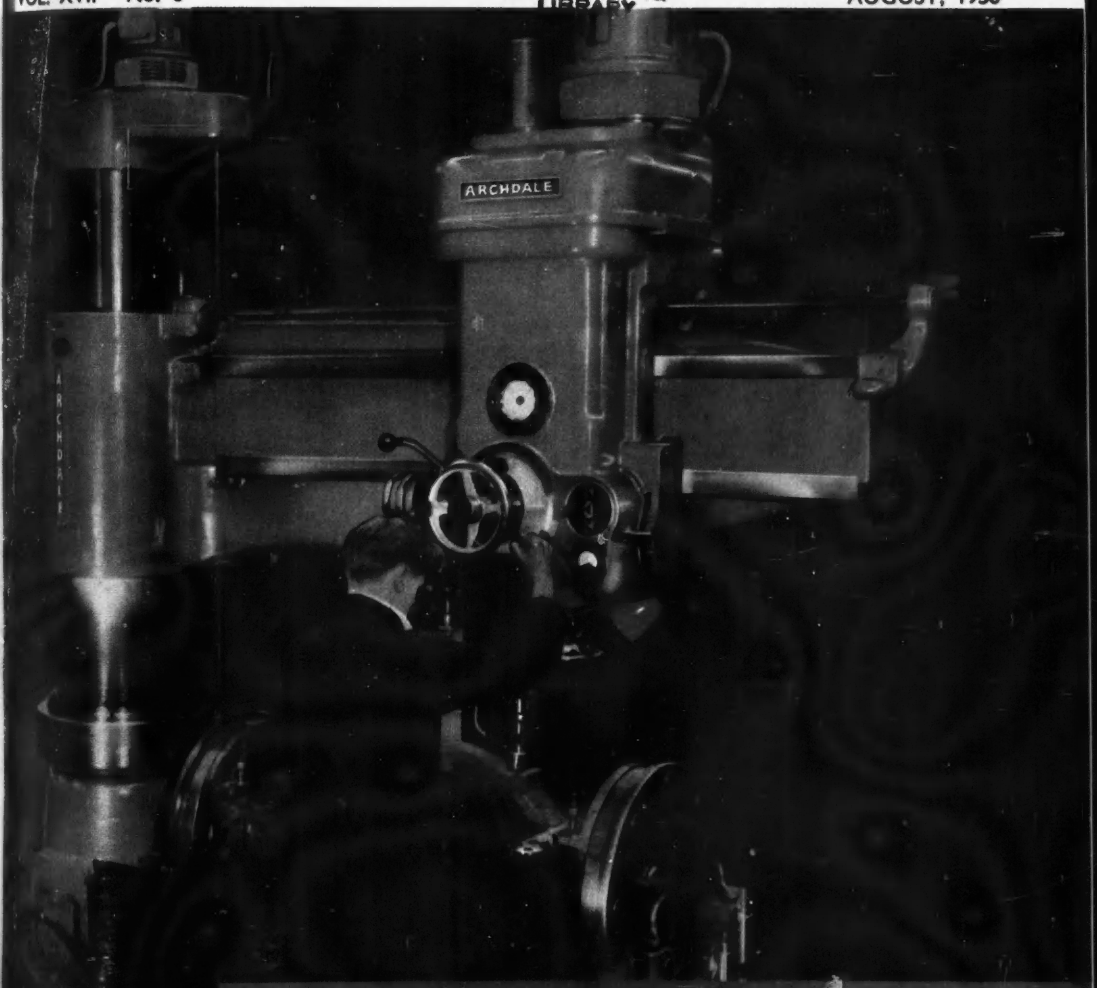

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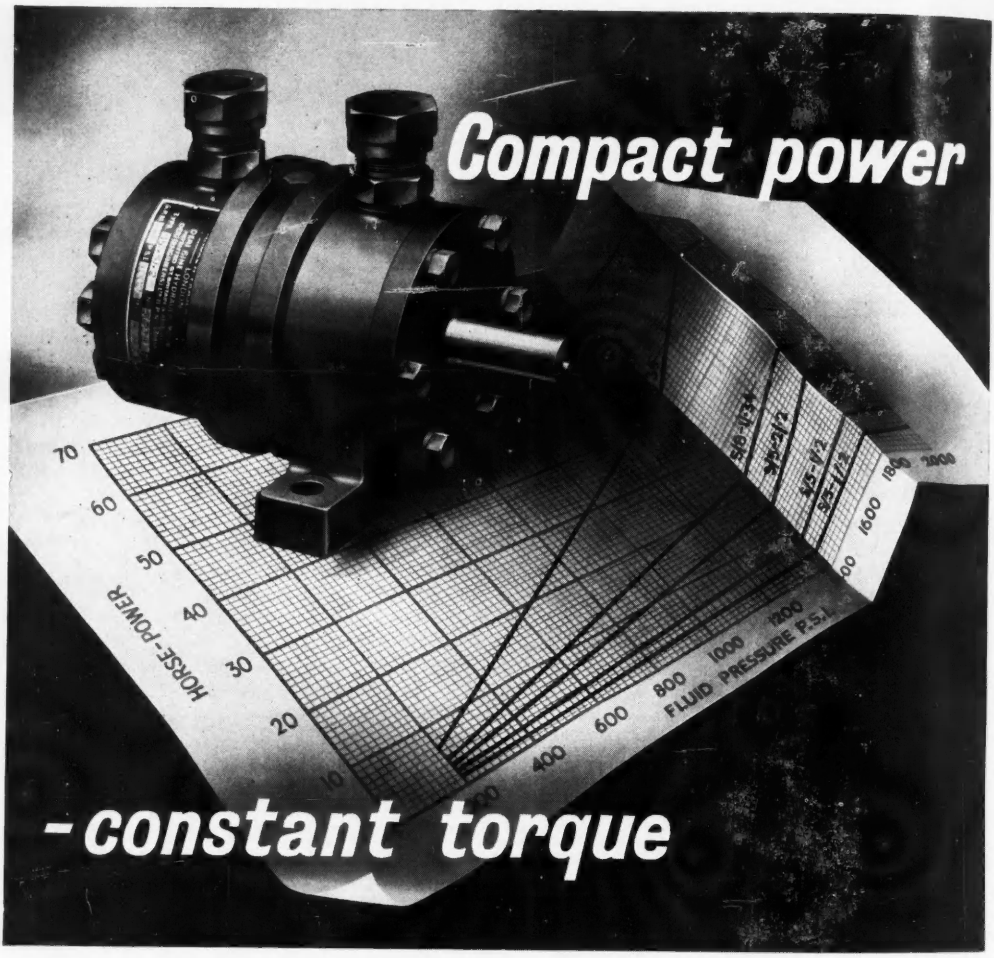

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *CAST BERYLLIUM-COPPER FORGING DIES*

Manufacture of a forging die is a very costly process, involving all-over machining of a forged steel die block and slow profiling of the cavity, followed by heat treatment to provide the necessary hardness and impact resistance. To meet the problem of making prototype and other short-run forgings quickly, the use of cast beryllium-copper dies has been investigated. This metal has a number of economic advantages over the use of steel dies. Beryllium-copper is readily cast with ordinary non-ferrous foundry equipment. The die can be cast to shape easily, and requires only the removal of the rear portion of the cast block, milling of the contact surfaces, and polishing of the die cavity. In the case of intricate dies, such a cast die could be produced in a far shorter time than a profiled steel die. An inherent advantage of beryllium-copper is that the metal has self-lubricating qualities. Its use therefore reduces considerably the amount of lubricant required during forging. It is reported that cast beryllium-copper dies have given successful service for aluminium and magnesium forging operations. Moreover, it is also claimed that in another instance some 400 stainless-steel parts could be forged with this type of die, without the die becoming unusable. An investigation is now in progress to determine the practicability of beryllium-copper dies for large aluminium and magnesium forgings made in 35,000- and 50,000-ton presses. The pattern can be made of soft wood, but should be built with a double shrink. The total shrinkage would be that of the beryllium-copper itself, plus the shrinkage allowance for the forging. In many cases the pattern could be made from plaster-of-paris.

● *BONDING OF VINYL LAMINATES TO METALS*

In providing fabricated metal parts with protective surfaces, there are limits to the thickness of coating which can be produced by painting or by plating operations. It is true that, by resorting to spraying techniques, heavier coatings can be produced, but the solvent required is expensive, and uniform coatings may be difficult to produce in complex shapes. A technique has recently been evolved by which thermally stable and chemically resistant coatings of from 0·004 to 0·020 in. in thickness can be obtained at a low cost by making parts from sheet which on one or both sides is laminated with a film of polyvinyl chloride. The lamination process employs a solid film material which has better heat and chemical resistance than can be obtained in solution-type copolymer resins suitable for spraying. The solid film can be applied to the sheet stock mechanically at a lower cost than by spraying, thus circumventing the problems involved in evaporating the solvent. The metals which can be coated are steel, magnesium, aluminium, iron, brass, and copper, and it is reported that some non-metallic materials have also been coated. That humidity will not affect the laminate or the bond appears to have been proved by long-time outdoor exposures and accelerated ageing tests. An important feature is that the coated sheet can be subjected to a number of forming operations, such as shearing, punching, drilling, press-brake bending, stamping, roll forming, and cold drawing. Where the surface has been damaged, repair can be carried out by replacement. After cutting out the damaged piece, adhesive is applied both to the surface area to be re-covered and the replacement piece and then allowed to dry, after which the adhesive is softened with solvent and pressed into place.

● *VIBRATORY POLISHING*

For the polishing of aluminium alloys a new method of final polishing by vibration has been developed which is claimed not only to save labour but also to produce better surfaces than those obtained by hand-polishing methods. The samples are ground and polished by the usual hand methods up to the final polishing operation. In the vibratory polisher the conventional soft-nap cloth is used, but it is cemented to the inside of a bowl which forms the polishing head and which is caused to vibrate by an electromagnet. The abrasive is applied to the moistened cloth and the samples are loaded into the bowl, the vibratory motion of the head polishing the specimens and at the same time causing them to rotate so that the polishing direction is changed constantly. Weights are added to the specimen to speed the polishing action. After polishing, the samples are removed, washed, and are ready for examination. The polishing machine consists of a stainless-steel bowl, a heavy base containing the electromagnet, and a controller for adjusting the amplitude of the vibration. The machines are built in bowl sizes from 5 to 36 in.

let's STAY hot under the collar

Consider: through the walls of a one-foot length of uninsulated four-inch bore pipe, carrying steam at 500° F, you waste the heat produced by one ton of coal, every year! If this inefficiency gets *you* hot under the collar, how do you think your steam pipes feel—under their collars and flanges, round their bends and valves? If they're hot to you, you're wasting fuel by the ton. And that's where a little Fibreglass can save you a lot of money. In rigid sections, compact and lightweight, thickness for thickness, there's nothing in the world to beat it for efficiency. Moreover it is easily mitred to proof awkward corners against heat leaks. Other, even more difficult situations, and temperatures above 500° F and up to 900° F, are covered by Fibreglass in *flexible* sections.

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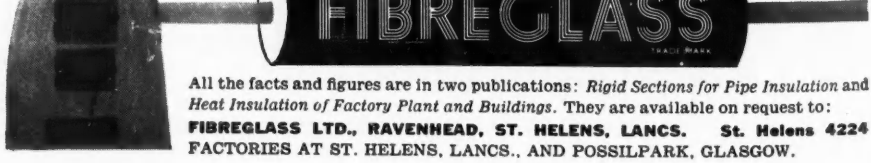

All the facts and figures are in two publications: *Rigid Sections for Pipe Insulation* and *Heat Insulation of Factory Plant and Buildings*. They are available on request to:
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The vibratory motion has a horizontal rotational component which provides the polishing action, combined with a smaller vertical component for moving the samples around the periphery of the bowl. On the vibratory polisher samples may be polished individually or in groups and can be removed or added at will. Various diameters, lengths, and shapes of specimens may be polished together and usually need not be plastic-mounted. The method has not yet been successfully applied to all the aluminium alloys, some additional hand polishing being required on very soft materials.

● *NITRIDED-FILM RESISTORS*

There are many electronic applications where resistors of small size and great stability are required. Recent investigations have shown that film resistors with either chromium-nitrogen or chromium-titanium-nitrogen film may have certain advantages for such uses, since they possess many of the desired properties. It is reported that in the one-watt size, such resistors can be made with resistance values in the megohm range with a temperature coefficient of resistance less than 0·01% per °C. Furthermore, unsealed Cr-N and Cr-Ti-N resistors operating at full rated load at an ambient temperature of 150°C exhibit a resistance change of only a few per cent in 1000 hours. In the 0·25-W size, resistors with values of several hundred thousand ohms more can be made, with properties similar to those stated above. Investigations have shown that Cr-N resistors show greater potentiality than Cr-Ti-N from the standpoint of resistance, but so far they have not shown sufficient consistency in properties. The Cr-Ti-N resistors, however, can be made with good reproducibility of properties. The latter can be specified for applications (1) where resistance values less than 2 megohms in the 1-W size and 250,000 ohms in the 0·25-W size are specified; (2) where excellent moisture resistance is imperative ; (3) where a temperature coefficient of resistance of less than 0·015% per °C over the range from −65 to +150°C is needed ; and (4) where a permanent resistance change of less than a few per cent in 1000 hours can be allowed for full-load operation at an ambient temperature of 150°C.

● *PROTECTIVE METALLIC-OXIDE COATING FOR METALS*

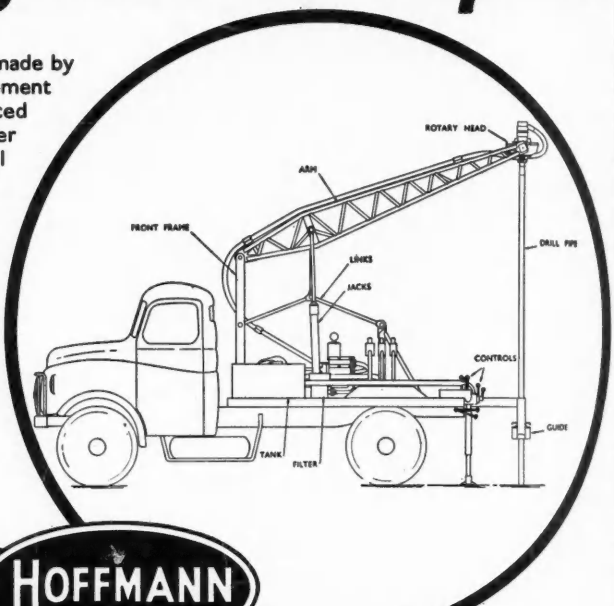
Recent years have witnessed the development of protective coatings for gas-turbine parts exposed to the action of fuel-oil slags containing vanadium. An outstanding difficulty experienced in the application of such coatings appears to have been the achievement of perfect adhesion. It is obvious that indestructible adhesion of the protective layer to the surface to be protected is essential, if erosion and corrosion of the parent metal are to be avoided when it is exposed to high-velocity hot gases. A recent invention describes a coating which is claimed to be free from this disadvantage and which is composed of a layer of powdered metallic oxide of high melting point, such as oxides of aluminium, beryllium, thorium, and zirconium. Instead of applying the oxide to an intermediate coating of enamel, as has already been suggested, the inventors propose to unite the powdered oxide directly with the surface to be protected, either by rolling, pressing, or hammering. For instance, where sheets have to be provided with a protective layer, the application of the layer is carried out by spreading the metallic oxide in powder form compactly and uniformly between two sheets, whereupon the whole assembly is rolled either hot or cold. It is stated that, when the sheets are afterwards separated, each sheet has a uniform protective coating on one side which adheres firmly to the metallic surface. The metallic-oxide powder penetrates into the surface of the metal and unites well with the metal because, even at a temperature of 1000°C, the grains are still very pressure-resistant and therefore are not deformed. The grain size of the powder particles may vary between one micron and one millimetre. If desired, the oxide coating itself may be provided with an additional protective layer.

● *BIMETALLIC MAGNETOSTRICTIVE ELEMENT*

It is well known that most apparatus used for the generation of ultrasonic vibrations are based on the magnetostrictive principle. Typical of this type are marine depth-sounders, dust precipitators, drills for piercing brittle materials, and emulsion mixers. In these applications the active element is a magnetic circuit formed by a metal or alloy with a high magnetostrictive coefficient ; however, in all such materials known the mechanical effects are relatively small. If, for example, a bar of nickel of 1 metre in length is subjected to a magnetic field of sufficient intensity for producing magnetic saturation of nickel, the bar will shorten by 0·03 mm. According to a recent patent it is possible to produce much greater mechanical effects if the active element is formed of a bimetallic assembly of two metals or alloys having different coefficients of magnetostriction, the construction of such an assembly resembling that of the well-known bimetal thermostat element. The two parts forming the bimetal magnetostrictive strip are preferably flat and welded along their entire length. The choice of the two materials is usually made to obtain maximum sensitivity, which can be achieved by using one material with a high negative magnetostriction coefficient such as nickel, and the other with a high positive coefficient, such as a ferro-nickel alloy containing

Revolving into the depths

The new Drillmaster 300 P.A. made by Hands-England Oilfield Equipment Ltd., represents an advanced approach to the truck/trailer mounted prospecting drill problem. To facilitate penetration of the drill, the rotary head spindle as illustrated, is supported throughout by Hoffmann ball and roller bearings. These adequately cater for all radial and thrust loads during drilling.



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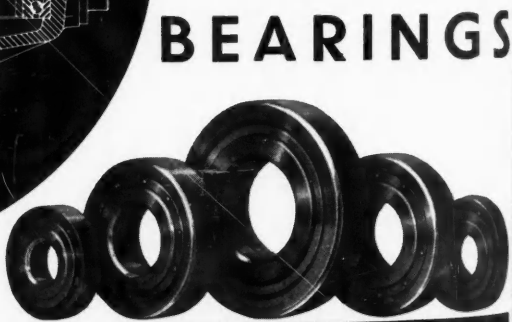
Bearing arrangement in the rotary drilling head.

BALL AND ROLLER BEARINGS



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35 to 65% nickel. The choice of the two materials may, however, also be influenced by other technical considerations. Thus, if the element is to be subjected to considerable temperature variations, the thermal expansion coefficient of the two materials may have to be taken into account. In dynamic applications, account will also have to be taken of the elasticity modulus, the specific weight of the material, etc.

● *ANODIZED-ALUMINIUM MAGNET WIRE*

A recent announcement states that a continuous production technique has been developed for producing insulated magnet wire by building up a ductile anodic coating on aluminium wire. The development is said to be still in its early stages, so that further research is required not only on the wire itself, but also on associated problems resulting from the use of a new material with different operating characteristics. It is considered that the use of anodized-aluminium magnet wire, in place of copper wire insulated with organic films, will offer the possibility of building equipment which is cheaper, lighter, and capable of running at a higher temperature. The possibility of using aluminium magnet wire with aluminium oxide insulation has been under investigation for many years, but until now anodic coatings have been too brittle and production rates have been too slow to be economically feasible. The new process is claimed to provide an insulating oxide film on aluminium at commercial speeds, and to produce a film of sufficient ductility to withstand the necessary stressing and flexing incurred by winding operations. The wire now produced may be bent around a mandrel with a diameter five times that of the wire itself, without impairing film adhesion or dielectric properties. The breakdown voltage which may be achieved depends upon the thickness and density of the oxide film built up on the wire. Under dry conditions, breakdown voltages up to 500 V are obtainable, but at this level the necessary oxide coating has reduced ductility and adhesion. At breakdown voltages between 200 and 250 V, adequate ductility for machine winding is obtainable, and at voltage levels of 100 V or lower a higher degree of flexibility is stated to be achieved. For a 200-V insulation, the thickness of the coating is approximately 0·0004 in.

● *ALLOY WITH CONSTANT ELASTIC MODULUS*

In cases where instruments or control devices must operate within close limits of accuracy under widely varying ambient conditions, the effect of temperature upon the elastic modulus of component parts may become a critical problem. This will hold especially true in the case of highly stressed parts where load deflection is important. A new material now available is characterized by a constant elastic modulus over a range of temperature from — 50 to + 150°F, and is an alloy, the chief contents of which are 41 to 43% nickel, 4·9 to 5·5% chromium and 2·2 to 2·6% titanium. The carbon content of the material is 0·06% maximum. This alloy can be precipitation-hardened to develop high strength, combined with low hysteresis and drift. By proper control the precipitation-hardening treatment can be varied so as to give a thermoelastic coefficient of any desired value near zero. Important applications of the new alloy would appear to be cases where stressed members must not show relative changes in deflection due to temperature variation, e.g., for helical and flat springs, Belleville washers, diaphragms, bellows, Bourdon tubes, torsion bars, etc. Another application appears to be in magnetostrictive components. In the field of acoustics the alloy has so far been used for tuning forks, vibrating reeds, electromechanical band-pass filters, and resonators, where its constant-modulus property manifests itself as a constant temperature coefficient of frequency. Disadvantages of the alloy are its low electrical conductivity and its poor thermal conductivity. The only claim for corrosion resistance that can be made for the material is that it resists industrial atmospheres, provided that in highly humid atmospheres no condensation takes place on the metal.

● *HIGH-TEMPERATURE ALLOY FOR STEAM-TURBINE BLADES*

As the operating temperature of steam turbines can be expected to be increased to 1200°F within the next few years, various new alloys are being considered as blade materials. In this connection information has become available on the development of a cobalt-nickel alloy which at 1200°F is said to have properties similar to those of 12% chromium steel at 900°F. The 100-hr creep-rupture life of the new alloy is stated to be approximately 50,000 psi at 1200°F, its damping capacity being about ten times that of similar alloys. Furthermore, it is claimed to be nearly five times as strong as the 12% chromium steels. It appears that the development of this alloy is based upon the fact that the mechanical behaviour of a given alloy depends, at least in part, on its magnetic properties, and those engaged on this project point out that after several years of research they have discovered how to obtain alloys with specified mechanical properties by control of their magnetic structure. They state that this knowledge makes it possible to predict the behaviour of an alloy composed of given metals in different proportions. This would indeed appear to represent a major advance in metallurgical research. In investigating the damping properties of metals essential for

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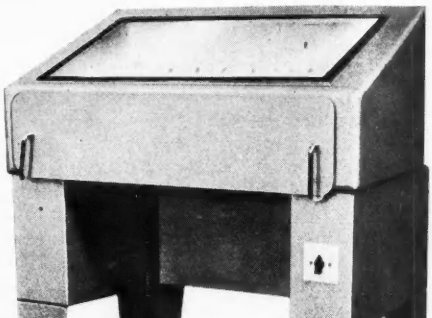

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a turbine blade, it was found that damping in chromium steel is caused by the magnetomechanical hysteresis effect. Proceeding from this premise an exhaustive study was made of the magnetomechanical effects in metals, including the well-known tendency of certain metals to change their dimensions under the influence of a magnetic field.

● *DIMENSIONAL STABILIZATION OF THERMOPLASTIC FILM*

It is well known that organic thermoplastic film, such as vinylidene chloride copolymers, which has been stressed during the course of its production for the purpose of effecting orientation is subject to internal strain. As a result of this strain the dimensions of the film may change, often to a non-uniform extent, during storage or exposure to heat. Various means are known to render such film resistant to dimensional change, but most of these methods are applicable only to the treatment of single thicknesses of flat film. Since much of the commercial plastic film is produced originally in tubular form, and may be stored or shipped as rolls of flattened tube, the usual treatment can be applied only after the tube is slit and opened to a single thickness. A recent patent specification describes a novel method of rendering tubular oriented thermoplastic film dimensionally stable, and this method can be made an integral step in the production of such film. The method employs an apparatus which makes it possible to inflate with a gas a portion of a continuous length of the previously oriented tubular thermoplastic film. The inflated portion is then exposed to evenly distributed radiant heat about its periphery. The process is made continuous by moving the film tube continuously and successively through two sets of pinch rolls, between which the radiation zone is located, and maintaining constant gas pressure in the inflated portion of the tube between the pinch rolls.

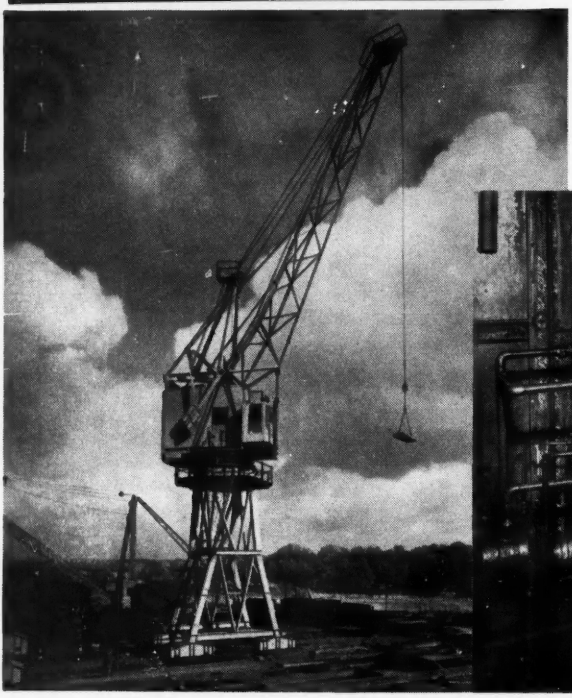
● *ELECTROPLATING OF ZIRCONIUM AND HAFNIUM*

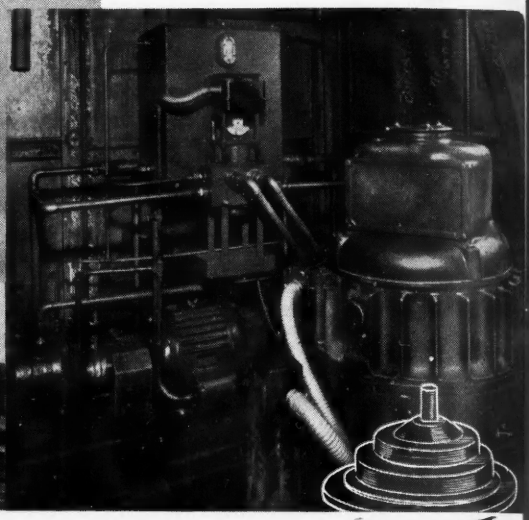
Zirconium metal readily forms a protective oxide film which resists removal by conventional methods. None of the usual methods for cleaning other surfaces prior to electroplating, such as the conventional processes for carbon steel, stainless steel, or chromium, can therefore be successfully applied to the preparation of zirconium for electroplating. In fact, if electroplates are applied to zirconium after it has been cleaned by conventional means, they can be easily peeled from the zirconium surface. The poor adherence of electrodeposits on zirconium prepared by conventional methods becomes especially apparent on heat treatment of the plated article, when separation of the electroplate from the zirconium surface may result. While this separation may be due to several factors, it is believed that the formation of molecular hydrogen at the interface of the basis metal and the electroplate is largely responsible, as the hydrogen expands during heat treatment and produces localized blisters. According to a recently issued patent specification, it has been found that zirconium and zirconium alloys can be chemically cleaned by etching the surface with an aqueous solution of ammonium fluoride and hydrofluoric acid, and that this etching will provide a surface upon which an adherent coating can be produced by electroplating. The complete process for applying an adherent electroplate to zirconium surfaces comprises three operations, i.e., (1) etching the surface of the metal with the above-mentioned acid bath, (2) electrodepositing the plating metal on the surface of the zirconium, and (3) heat treating the composite article. Heat treatment is carried out at temperatures from 1200 to 1600°F and serves to produce a diffusion bond by alloying the two metals. It is claimed that the same process, in all its stages, can be applied to hafnium and hafnium alloys.

● *AUTOMATIC MICRO-IMAGE FILING SYSTEM*

A micro-image data-storage and retrieval device has recently been developed, and provides rapid access to any one of 10,000 information-containing frames recorded in miniature on a sheet of microfilm, 10 in. square. The machine operates on a continuous basis, automatically searching the microfilm and photographically printing out one frame every two seconds. The machine is particularly suitable where large volumes of data must be assembled in a predetermined sequence from a master random file. Such information may be in the form of pictures, drawings, sets of numbers, letters, or other symbols, or even single stages of electronic circuit diagrams. The quantity and kind of data are limited only by the size of the individual frame and by the resolution of the photographic film emulsion. Although the basic storage capacity of the machine is for a 10,000-frame matrix, this matrix can be interchanged with others. The input to the machine is from a perforated teletype tape containing the coded locations of the desired frames in the order in which they are to be printed out. The assembled data produced issue on a strip of photosensitive paper, 10 in. in width and of any required length, the individual frames being enlarged to ½-in. squares. Fifteen successive frames are printed in a row across the width of the strip by means of a step-positioning mirror which automatically advances the image one space on the photographic paper for each print made.

HELIOCENTRIC GEARS IN ACTION No.5





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The "Mechanization Profile" for Measuring Automation

By J. R. BRIGHT. (From *Mechanical Engineering, U.S.A.*, Vol. 78, No. 7, July 1956, pp. 620–624, 1 illustration.)

THE production of goods involves a number of basic functions. The production operation, i.e., processing, is instinctively visualized as the heart of the automatic factory, but design, handling, storage, maintenance, and measurement also are essential. If the plant is to approach automaticity, even remotely, there must be a high degree of mechanization of each of these functions, not merely of processing.

This paper offers an analysis of mechanization and a method of charting it which has proved useful in studying some fifteen so-called automation plants. A simple chart can be constructed that will suggest the nature of mechanization generally associated with these functions. Such a chart does not need to be absolute and precise to show that to-day there is no such thing as an automatic plant or even a push-button plant, and that mechanization is not found equally distributed through any single production sequence, let alone any whole plant or industry. It should also be noted that automation can be analysed in terms of three different qualities, i.e., (1) the span of mechanization, covering the particular portion of a given total manufacturing sequence over which mechanization extends ; (2) the level of mechanization, covering the degree of mechanization which characterizes the particular function or activity ; and (3) the amount of mechanization, covering the prevalence of the mechanization of a given function or activity in the industry as a whole.

THE MECHANIZATION PROFILE

The concept of degrees of mechanical art approaching automaticity, i.e., levels of mechanization, suggests that there must be different operations which machines can perform. In what way does machinery supplement man's muscles, his senses, his mental processes, and his judgment? Are there significant differences in the levels of mechanization? And if automation is so different, where does it fit in?

It would seem that it is quite possible to consider these questions by a systematic qualitative analysis of the functions of simple and complex machinery. It has been possible to distinguish seventeen levels, though this particular breakdown cannot be defended too vigorously. Examples can be cited which would in some degree confound this or any other classication. Doubtless, additional subdivisions could be defined. Furthermore, some of these levels may be inextricably tangled with much lower levels. Nevertheless, it can be said that the following seventeen levels have been found to be fairly consistent and usable :—

Level (1) :—*Hand.*

The least mechanical method of construction employed by man generally involves the use of his hands, and occasionally of his feet, knees, elbows, or even his lungs (as in glass blowing). No tool of any sort is used. Examples include manual lifting and packaging operations, inspection, and many assembly operations.

Level (2) :—*Hand Tools.*

An enormous amount of work is performed by the human hand, aided by non-powered tools such as hand wrenches and pliers, even on automobile assembly lines.

Level (3) :—*Powered Hand Tools.*

The next step is to provide mechanical power to the tool held by the worker. The power screwdriver, the portable drill, and the portable welding machine exemplify this level of mechanization. Power supplements the worker's muscles, but actual guidance of the tool is still under his control.

Level (4) :—*Hand-Controlled Power Tools.*

The simplest form of machine tool appears at this level. A drill press, for instance, provides power to the tool and also a framework for guiding the tool. Application to the workpiece is physically actuated by the operator, who controls the amount of action, as well as its duration. In other words, the machine performs within fixed dimensional limits and rates built into it, but the operator controls the application of such action. Such a machine can be mobile or stationary.

Level (5) :—*Fixed-Cycle Power Tools* (*Single Function*).

Machines of this type repetitively perform a single action which is mechanically fixed within definite limits. A drilling head, arranged so as to advance, drill a 1-in. hole, and retract, all automatically, reflects this type of mechanization. A belt conveyor moving at a set speed also performs a single action in an unvarying way.

It is implied that this machine action is mechanically (automatically) controlled, even though an operator may have to push a button to start the machine and stand by as an observer ; however this does not invalidate the basic point that the machine itself controls a simple action over the desired range of performance.

Level (6) :—*Programme-Controlled Power Tools* (*Sequential Functioning*).

This step is similar to the previous one, except that the machine performs a series of actions in sequence, operating in one or both of two basically different ways ; i.e., (1) the workpiece is held in a given position, and the different tools are brought to it for the period of their individual cycles—the principle of the automatic turret lathe ; and (2) each operation is performed at its own fixed station ; the workpiece is then passed to successive stations under automatic timing, positioning, and material-handling control—the principle of a dial-indexing machine tool. Transfer machines used in the automobile industry combine both of these concepts.

It is rather interesting that this level of mechanization is found in many automatic home appliances, all of which work on the first principle rather than on the second. In the industrial plant, because of unique variations in the average product, more and more emphasis is being put on the second approach for assembly work, though the first is still useful for processing.

Level (7) :—*Remote-Controlled Power Tools.*

While it might be argued that this is not a clearly defined level of mechanization, since it is also found, fragmentarily at least, three levels earlier, it seems desirable at this point to establish remote control in the scheme of things. The principle is that the control of the power tool is located a significant distance from the tool itself. Where a single tool is concerned, this holds no special significance, but, when a group of power tools is equipped with remote control, the impact on mechanization mushrooms. It becomes possible to assemble the control of a series of machines in one central location. Thus, the whole industrial art is advanced an appreciable step closer towards automaticity.

Remote control implies less personnel, but this is not the most important implication. Centralization is far more important. It generally means much faster " reaction time " to the needs of the various production operations, particularly as they affect each other. Thus, improvement in quality, reduction in scrap, and higher machine efficiency through optimum operation of the plant as a whole are likely to follow.

This level of mechanization eliminates the delays and errors inherent in the communication of information between human beings at widely scattered locations. The lack of this level of mechanization probably is responsible for the excessive paper work, elaborate production-control systems, and general inefficiency of flow apparent in the average job shop. (It is not meant to imply that it is always practical or economical to change procedure. The thought is merely to emphasize that such " looseness" in control is the target of this seventh stage of mechanization.)

Level (8) :—*Actuation by Introduction of Workpiece or Material* :—

In all the previous phases of mechanization, the human element is required to actuate the system. In advanced mechanization even this need begins to disappear.

It is no longer uncommon to find machines which " idle " or remain inactive until started by the introduction of the workpiece. This is a feature of many new compound machine tools, whereas the transfer machines of five years ago usually cycled continuously, whether or not a workpiece was present.

Level (9) :—*Measurement of a Characteristic.*

A move is now made into levels of mechanization where there is a new emphasis on control, rather than a pattern of operation. There are machines that not only change the form of the object but, with certain mechanisms added, also measure some characteristic—weight, temperature, a dimension, a shape, a colour—either before, during, or after production.

Level (10) :—*Signalling the Measurement Value.*

A logical refinement of the previous level is to include a device which will signal when the measurement value is in a certain area or reaches a certain limit. In effect, the machine calls for human help. Sometimes the machine is designed to yield several kinds of signals (different-coloured lights or sounds), so that the nature of the measurement value can be quickly grasped by the human machine tender. This is particularly useful in the case of errors or difficulties.

It is a very short further step—so short that it is not regarded as more than a special case of this same level of mechanization—to have the machine shut down until it is " cleared " by its attendant.

Level (11) :—*Recording Performance.*

Often, it is desirable to have a record of machine performance. This may range from a mere count of the number of pieces produced (or tons, gallons, yards, and so on) to a record of individual values of the characteristic measured almost moment by moment.

A recent refinement has been to incorporate signalling with recording. At least one such data-scanning device prints values in red if the value exceeds a preset limit for a particular instrument. Thus, it is possible to see at a glance which values are out of control.

Level (12) :—*Changing Speed, Position, or Direction, According to Measurement.*

One of the most important advances towards automaticity is the development of machinery that automactically modifies its action in accordance with the information received through some kind of sensing device—the principle of feedback.

However, the idea of feedback itself seems to employ different degrees of mechanization. At this particular level, the correction or performance based on the quality of the output is not under consideration. Rather, the machine is controlled by a signal and is not influenced by the precision of its own processing action.

Perhaps, this phase of mechanization may be distinguished from earlier levels by saying that the performance of the machine is controlled by a signal rather than by a fixed programme. It is more flexible in action and in the time dimension, but, while this machine changes its action at a signal, it does not inspect its own performance.

Level (13) :—*Segregating or Rejecting, According to Measurement.*

Implicit in the previous level is the next step of automatically accepting or discarding a product that does not meet a prescribed standard. In Level (10) all the machine does is to inspect and signal for human help ; it takes no action on sub-standard work. However, at Level (13) machines not only measure and decide on acceptability but also dispatch the work accordingly.

Although this is a high level of mechanization in the sense that it employs decision and physical separation, the actual execution can be very simple indeed. " Measurement " here may be nothing more than the sensing of form and the adaptation of some kind of chute, divider, or separator which will direct one form one way and everything else another. In very elementary form, a punch press may be rigged to separate the scrap from the finished parts, or a bottling machine may include a weighing device which will separate out incompletely filled bottles. " Decision " is more or less a " yes or no " choice, although it may involve a choice from three, four, or even more alternatives.

Level (14) :—*Identifying and Selecting Appropriate Action.*

Here, the machine examines the incoming product and adjusts itself to perform accordingly. For instance, a recently introduced machine tool receives two types of castings. It automatically distinguishes between them and puts each casting through a different set of machining operations as the two pass through the same series of work stations.

Admittedly, this is not very much different from the preceding level. The significance lies in the fact that the response of the machine covers a wider range and is more complex. Instead of a single-action response—an inspection and materials-handling sequence—there may be a modification of performance involving a whole series of varying subsequent actions.

Level (15) :—*Correcting Performance After Operating.*

On this level the machine examines its performance and then readjusts itself accordingly to turn out a more nearly perfect product. To a very limited extent, this feature has been employed in some machine tools, which will grind or perhaps otherwise remove material, inspect it, and then translate the inspection information into corrective action, so that the next piece is machined properly.

However, even though inspection and correction are automatic and tied together, the inspection after operation implies a time lag, and the more time, the more opportunity for faulty parts to be created before the correction is introduced.

Level (16) :—*Correcting Performance While Operating.*

Theoretically, the ideal machine would control itself so that it would never turn out a faulty part. It would inspect continuously and modify its performance quickly enough to avoid potential faults.

It is hard to find machines that fully meet this definition. Perhaps the nearest are the electrical machinery devices with their precise output controls. They will maintain speed, torque, voltage, or current, as the case may be, within amazingly fine limits. Some chemical operations, particularly the control of temperature and of pressure, also fall within this area.

Level (17) :—*Anticipating Required Performance and Adjusting Accordingly.*

There are a few isolated examples of machines that not only sense something and correct their actions but also extrapolate the governing data or act on a lead from the probability pattern (or otherwise anticipate the action needed to produce the required performance), and then regulate themselves accordingly. Self-guided missiles are an outstanding example.

Oil-refinery developments are beginning to get into this phase. Engineers visualize the application of instrumentation which will sense the change in a variable, predict what will develop and the corresponding series of changes needed in the process, and then change the various machine responses accordingly. This is more than the measurement of a characteristic and a response. It is the measurement of the rate of change in the characteristics, the anticipation of the control modification needed, and then the modification of a host of variables to hold the process within design limits.

Relationship Between Mechanization Levels

If these levels of mechanization are arranged in order on a chart, certain important relationships between them fall into place. Consider the nature of the power used at each of these levels. Only the two lowest ones use manual power ; all the rest are based on mechanical power. Even more significantly, the seventeen levels are distinguished from each other by the nature of their control characteristic.

The first four levels of mechanization all employ manual control. There is an interesting difference between Levels (3) and (4). At Level (3)—the powered hand tool—manual control can be thought of as embracing two elements, i.e., application and guidance. At Level (4), however, one aspect of this control job has been further mechanized—the aspect of guidance. The construction of the tool fixes the limits of the physical action. The operator merely guides the tool or " controls " it within certain mechanically fixed paths. He has only limited control in the three physical dimensions but retains complete control insofar as time is concerned.

In passing to the fifth level of mechanization—the fixed-cycle power tool—it is apparent that not only has the guidance of the tool been mechanized, but also its application in the time dimension. Other than starting and stopping the machine, or possibly modifying its speed, the tool is completely mechanically controlled. Level (6) is nothing but a more advanced form of Level (5). Level (7) has remote control, often applied to the next three lower levels ; this is inserted at this point because it enables the centralization of control of a number of machines.

At Level (9) a new force is becoming predominant in the control action. The environment, the product, or the nature of the operation itself at given moments becomes the initiating element of the system. Control here is no longer mechanical, fixed, or rigid ; rather, it is variable according to performance. The control indication may be prior to, or during, or after the production act has been performed.

In Levels (9), (10), and (11), the control response is not a specific action of the machine as much as it is a signalling action. The machine has verified the nature of the performance, and it either reports this performance and/or calls for human attention.

At Level (12), a new quality to control has been introduced. The control responds with action. All the succeeding levels of mechanization embody the idea that the machine measures completed, current, or impending environment, and modifies its major functioning accordingly. In the lower of these levels, the action response is very limited in character, whereas in the higher levels it is broader, richer, and much more complex.

The Meaning of Automation

Some disciples of automation see it as embracing the idea of automatic control. To them control, rather than mechanical automaticity, is the dominant factor ; indeed, automation is synonymous with automatic control. This group seems to be applying automation to the levels of mechanization from roughly (9) to (17). However, some of them insist that it is not really automatic control until it embraces only Levels (12) to (17).

Others lay heavy stress on feedback. They have said or implied in many ways that " true " automation embraces the idea of self-correction. However, automation is not quite so simple, as more careful analysis of these seventeen levels will demonstrate.

After examining these levels and their application to a manufacturing sequence, the questions arise as to what exactly is meant by automation, where it fits in, what is unique about it, and whether, in fact, it is new and different. It seems clear that practical industrialists who must use mechanization are interested in an end (i.e., automatic manufacturing), while many of the enthusiasts are obsessed by the means (i.e., automatic control, handling, or processing). Thus, to insist on automation as relating merely to a certain aspect or certain levels of mechanization is utterly foolish. Automaticity may or may not require self-regulation. It is important to realize that many highly automatic operations do not require performance control. There is nothing excellent, brilliant, or economic in employing higher levels of mechanization than are needed. Countless cases can be cited where automatic operation—or, more correctly, a high degree of automaticity—has been achieved on Levels (5) and (6). To the extent that the required activity is reasonably uniform in input, throughput, and output requirements,

there is no need of automatic control. Indeed, to introduce automatic control into many of these situations becomes ridiculous. Often it leads to a marked reduction in economic efficiency through high engineering costs, high maintenance costs, and limited flexibility.

This is not to deny the steady growth and important application of controls to reach new advanced levels of mechanization. Furthermore, experience is showing that direct labour reduction is not the only advantage—and often is not the major advantage—arising out of automaticity. Savings in material through reduction of scrap, reduction of inventory, and refinement in product design are often the major advantage. Improvement in quality has been the significant advantage in a number of cases. Rather, it should be stressed that countless machines and groupings of machines already have achieved and will continue to achieve the most economic level of mechanization far short of full automation.

Automation or Mechanization ?

From fifteen or so profiles made of actual operations, it is clear that :

(1) Most instances of automation turn out to be largely automatic-operation systems not embodying self-regulation. There is little or no use made of the higher levels of mechanization.

(2) With the level of mechanization varying widely as between industries and between parts of the individual production cycle, automation is being used to describe something on a significantly higher level of mechanization than previously existed in that particular activity or plant, rather than any certain minimum level of mechanization or automaticity. What is called automation in the bakery business, for example, is everyday mechanization in the automobile industry. This does not imply that one field is much more backward than another. Rather, economics, technical problems, and mechanical art vary widely between industries. Automation is relative, not absolute.

(3) Automation usually covers a very small part of physical manufacturing activity and next to none of the mental activity required. Since automation is being introduced as islands of automatic operation in the total sequence, it suggests the need for a thoughtful look. Are these islands adapted to further integration, either as a whole or as part of a larger island ? There is evidence that engineers should give more attention to long-range mechanization planning. Buying unrelated elements of automation piecemeal may be expensive and inefficient.

(4) A major element in achieving automaticity is the mechanization of handling. The conveyor in some form, and occasionally the monorail, is the heart of most highly mechanized plants. Processing is being built around, on, and into the conveyor. Automatic production is impossible without automatic movement. The automatic processing machine is only the first step, rather than the last, on the road to the automatic factory.

(5) A significant result of higher levels of mechanization is the reduction in space requirements for production facilities. With automatic controls, many machines are performing more functions than formerly, so that there can be less equipment. Other machines are being placed close to each other for transmission of fabricated parts. Handling systems are linking major production centres with each other and with raw-material and finished-goods storage. Less space is needed around production operations, because there are fewer operators, traffic passageways, and materials being processed.

(6) There is a very long way to go to reach full automaticity. Automatic processing is relatively easy. Automatic assembly is the glaring weak spot ; next to nothing has been done in this area except in the bulk-materials field and a handful of very high-volume discrete-part manufacturing plants. Product inspection, in spite of certain dramatic advances, also is astonishingly unmechanized throughout industry. Man's versatility, sensitivity, and power of discrimination, plus materials-handling ability, are unique. They make him far and away the most economic inspection " device " except for the very precise and/or the highly repetitive inspection activity. Where a combination of factors must be considered in inspection, e.g., cracks, flaws, appearance, texture, and general quality, it is a rare machine that can beat him.

A mechanization profile can be made both of the actual level of mechanization and of the theoretically desirable level. A systematic comparison of these two curves will highlight important gaps, and the engineer can then consider whether or not the expense and the time necessary to raise the level of mechanization for a given operation seem to be reasonable. Even more important, such analysis will suggest whether this effort might be better directed elsewhere in the total manufacturing cycle.

Refining the Profile

This profile technique is new and unrefined. It should not be adopted blindly or over-enthusiastically. Perhaps its greatest value is its use as an aid to orderly and careful consideration of new concepts and methods in mechanization.

Eventually, it may be possible to quantify the profile in some way so that productivity might be related directly to the level and span of mechanization. Perhaps, different systems might be compared quantitatively and, therefore, more accurately. This might lead to the ability to measure mechanization in absolute terms, so as to compare industries and systems and to measure historical progress. However, the user should be very careful not to be misled by this rough tool. He should always remember the following facts :—

(1) A profile can fall into lower levels of mechanization, and still the operation may be quite " automatic ". Many machines which are taken for granted actually perform and tie together a number of operations. Thus, the fixed-cycle machine provides a great deal of automaticity.

(2) There is nothing economically virtuous *per se* in the higher levels of mechanization. A system is neither " good " nor " bad " because it is high or low on the profile chart. It should not be assumed that mechanical achievement implies economic excellence. The point of diminishing returns is just as true in mechanization as in anything else.

(3) Automation is not absolute, but relative. It is not by accident but by design that a rigid definition has been avoided from the very beginning of this paper, and that a number of phrases have been used to imply the act of doing things " more automatically ". That is how automation actually shapes up—in current practice and for some years to come—as degrees, steps, and levels in the advance of mechanization.

In short, an intelligent analysis of mechanization will help to compare systems and to highlight weak spots. Thus, the mechanization profile may eventually become a useful tool which will serve to broaden our perspective of technical progress.

Brushless Variable-Speed Induction Motors Involving a New Principle

By E. R. Laithwaite, M.Sc., A.M.I.E.E.*

The electric motors described in this article are based on a new principle, which is perhaps most readily understood by considering a " linear " induction motor, i.e., a machine capable of producing a magnetic field travelling in a straight line. A developed diagram is often used to illustrate in a plane the winding arrangement of a cylindrical machine, and the stator of a linear induction motor is wound precisely according to this diagram. Such motors have found varied applications ; for example, they have been used to fire missiles[1], to launch aircraft[2], to pump liquid metal[3], etc. If a short linear stator is presented to the surface of a disc of conducting material, as shown in Fig. 1a, the disc will rotate at an approximate angular speed v_s/r where r is the effective radius and v_s is the speed of the field, given by $2pf$, p being the pole pitch and f the supply frequency. This last expression is the criterion for the speed of all induction motors, and thus, to vary the speed, either p or f must be changed. Variable-speed induction motors therefore fall naturally into two classes, according to whether p or f is used as a variable. An example of the first type is a pole-changing motor, whilst a commutator motor is an example of the second. If the stator block shown in Fig. 1a is moved bodily towards the centre, the angular speed of the disc will increase, since the same linear speed is attainable at a smaller radius. Such a device may be said to constitute a variable-speed induction motor, falling into neither of the classes mentioned above, since it is simply a form of mechanical gear. This device is not new, nor can it be exploited to give an efficient machine, being essentially wasteful of available disc surface.

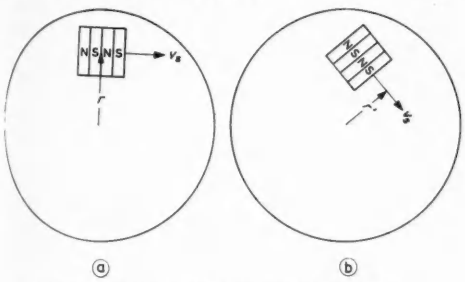

Fig. 1. **Simple disc model of the variable-speed motor.**

The new principle is based on the discovery that, providing the poles of the stator are wide compared with a pole pitch, increased speed of rotation can be obtained by rotating the stator block as shown in Fig. 1b, so that the travelling field is directed at a smaller radius r'. The speed of rotation is now ideally the same as that obtained by moving the stator of Fig. 1a bodily inwards to a radius r'. Fig. 2 illustrates the principle in broader terms. The array of north and south poles produced by the stator is travelling at a speed v_s in the direction shown. If the rotor is allowed to travel in the direction of movement of the field OA, its limiting speed will be v_s. If, however, it is constrained to move only along a line such as OB, making an angle θ with OA, it can in theory attain a speed of $v_s/\cos\theta$, since the effective pole pitch has been increased from p to p' $(= p/\cos\theta)$. It should be noted that rotor currents must be allowed to flow in

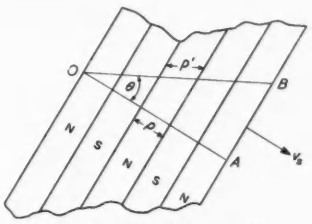

Fig. 2. **Principle of the new motor.**

paths conforming sensibly with those of the stator windings. Thus, if the speed is to be changed by varying angle θ, the rotor must in effect be an omnidirectional conducting sheet.

Experimental Disc Machine

The first experiments were conducted on an aluminium disc, 14 in. in diameter. The arrangement of the stator was as shown in Fig. 1, two four-pole blocks, 2×2 in., being fitted on opposite sides of the disc. It was found that, for small values of θ, the speed of the disc was given simply by $v = v_s/\cos\theta$, but for $\theta > 60$ deg., the actual speed fell below the value given by this equation.

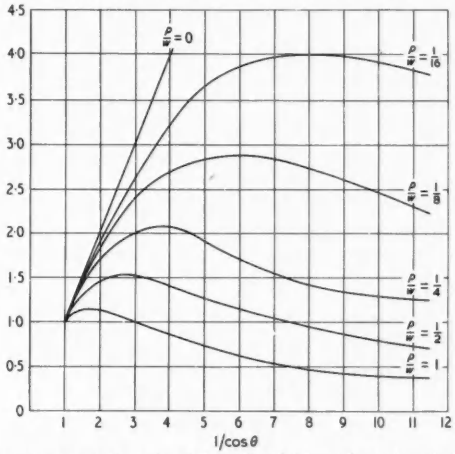

Fig. 3. **Theoretical speed variation with angle θ for various values of p/w.**

Based on a simple theory[4] developed to attempt to predict the running-light speed for any angle θ, the resulting equation for the rotor surface velocity v_r is

$$v_r = \frac{v_s}{\cos\theta}\left(\frac{1}{1 + p\tan^2\theta/4w}\right)$$

where w is the pole width.

This equation is plotted in Fig. 3 for various values of p/w. The early experiments on the disc machine adequately supported the theory.

The First Spherical Motor

Attention was now directed to the problem of making an efficient machine with a reasonable power output.

* Electrical Engineering Laboratories, Manchester University.

The disadvantages of disc machines are well known. The obvious development is to arrange the field to operate on the edge of the disc rather than on its surface, as in conventional machines, in which the disc edge is widened by making the rotor into a cylinder. Unfortunately, it is not possible to rotate the stator blocks on a cylindrical machine without fouling the rotor. A spherical type of construction is therefore necessary and is illustrated in Fig. 4, which shows the spherical rotor with one stator block in position. Several such blocks can be included

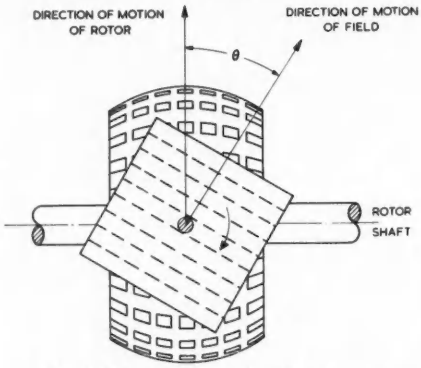

Fig. 4. **Schematic diagram of a spherical motor.**

around the periphery of the machine, opposite rotation being used to eliminate end thrust on the shaft. The rotor is made up of iron stampings containing, in addition to the conventional squirrel-cage of copper bars in slots, a number of peripheral copper bars crossing the conventional bars and solidly connected to the latter at all crossing points.

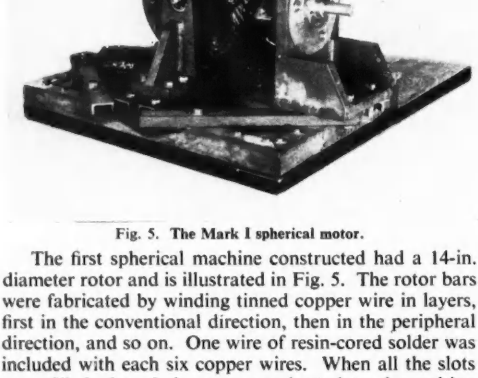

Fig. 5. **The Mark I spherical motor.**

The first spherical machine constructed had a 14-in. diameter rotor and is illustrated in Fig. 5. The rotor bars were fabricated by winding tinned copper wire in layers, first in the conventional direction, then in the peripheral direction, and so on. One wire of resin-cored solder was included with each six copper wires. When all the slots were filled, the whole rotor was heated to the melting point of the solder. This machine was found to have a speed range of over 3:1, but a maximum efficiency of only 35%. This speed range was regarded as highly satisfactory, but the efficiency was very poor.

Subsequent experiments were conducted in an attempt to analyse the losses. Fig. 6 shows a set of results taken with this machine at constant current. The difference between curves (b) and (c), as shown by curve

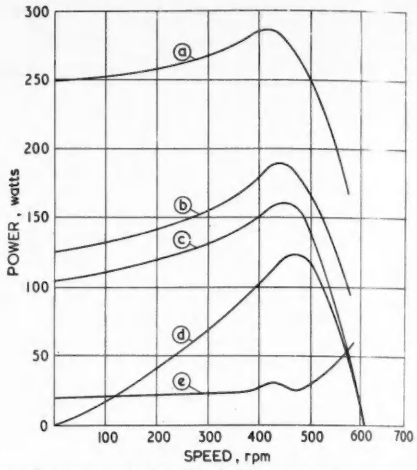

Fig. 6. **Results of load tests on the Mark I spherical motor.**
(a) Input power.
(b) Input power less stator-copper loss.
(c) Synchronous watts (torque × synchronous speed).
(d) Output power.
(e) Difference between curves (b) and (c).

(e), should be merely iron loss and stray load loss, and should be a small proportion of the total power for a good machine. In this case, however, these losses were large and varied with speed in a very unusual manner.

One of the unconventional features of the spherical motor is that the stator is essentially of a discontinuous nature and does not close on itself. Such machines have been termed " short-stator " machines and have been the subject of considerable interest in Russia during the last twenty years[5,6,7,8,9]. The first point to note is that, when the machine is running with a small slip, the time spent under a four-pole stator block is only a fraction of a cycle of slip frequency, and it is doubtful if the rotor is behaving in a way which is anything like comparable with the rotor of a conventional machine.

To investigate the nature of the actual rotor current under working conditions, a small transistor amplifier with a gain of 100:1 was fitted to the rotor of the Mark I machine. This was used to amplify the voltage developed across a very low resistor in series with a rotor bar. This resistance was made about 10% of the bar resistance, so as to leave the rotor-current distribution sensibly unaltered. The amplified voltage, proportional to rotor current, was brought out through slip rings. The results are shown in Fig. 7. At a slip σ of 1/3, just over one cycle of slip frequency is observed during the time the bar is under the stator, as would be expected. There is also some evidence of transients on entry to and on leaving the block. The running-light condition emphasizes these transients, which are thought to produce some spurious losses. Nevertheless, even when running light, a fraction of a cycle of slip frequency is still to be seen, indicating a small slip. Search coils were now incorporated on the stator pole faces. These revealed a sensibly constant flux density over the block length at standstill. On running light, however, the flux density was found to be virtually zero at the end where the rotor bars entered the block, and to increase linearly towards the leaving end. This phenomenon provides a clue to the curious shape of curve (e) in Fig. 6, which subsequently became known as the " missing-watts " curve. At entry, un-

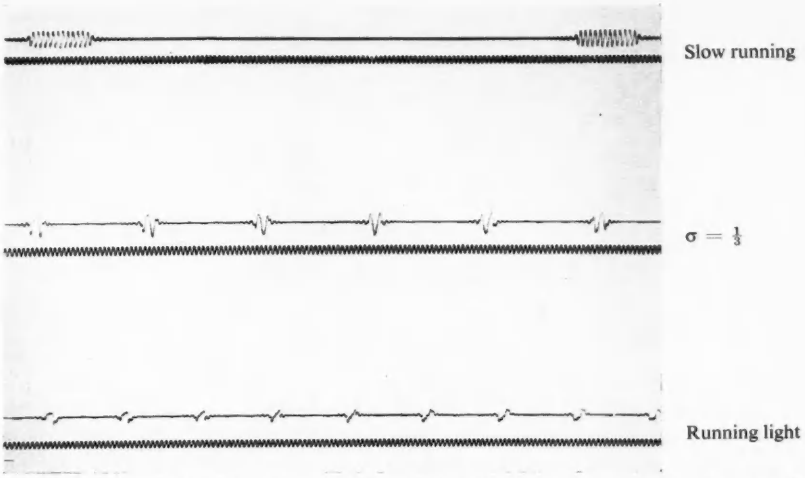

Fig. 7. **Oscillograms of rotor-current in the Mark I spherical motor.**

magnetized iron surrounded by copper loops is entering the stator block. Without an infinite voltage, the flux through the loop cannot be instantaneously changed. A rotor current equal and opposite to the stator current is set up at the point of entry. This produces rotor-copper loss without producing any torque. At least a part of the missing watts, therefore, consists of rotor-copper loss, since the actual loss is greater than the rotor-copper loss as calculated for conventional machines. The difference has been termed " excess rotor-copper loss".

In short-stator machines, it is apparent that every part of the machine is being operated under transient conditions at all times, even though the machine may be running at a constant speed under a constant load. Conventional induction-motor theory is thus not applicable to spherical motors, and a new and rather complex theoretical approach has been undertaken.[10] Only the most important results affecting the design of spherical machines will be quoted here.

The major difference between short-stator machines and conventional induction motors is to be found in the flux distribution under a stator block. Assuming perfect coupling between rotor and stator, for example with a rotor speed equal to the synchronous speed of the field, the flux density at any point is proportional to the distance of that point from the point of entry. The flux building up linearly from zero is purely a quadrature flux with reference to the stator current. Taking into account imperfect coupling, and allowing for what is termed " magnetising " current in conventional theory, this quadrature flux builds up exponentially towards a limiting value. The theory has been developed in terms of a machine fed from a constant current source. In a simplified form of this theory perfect coupling is assumed. The equations relating the flux density to the distance from the point of entry are then

$$B_p = \frac{\rho_r I_s}{\sigma v_s}\left(1 - \cos\frac{\pi\sigma s}{(1-\sigma)p}\right)$$

$$B_q = \frac{\rho_r I_s}{\sigma v_s}\sin\frac{\pi\sigma s}{(1-\sigma)p}$$

where B_p is the component of flux density in phase with the stator current density I_s, B_q is the component in quadrature with I_s, s is the distance from the point of entry, and ρ_r is the rotor surface resistivity.

The Second Spherical Motor

The first spherical machine had a low efficiency, not merely, however, because of the peculiarities of the short-stator effect. The stator-copper loss was excessive, the iron was of poor quality, and so on. A second machine

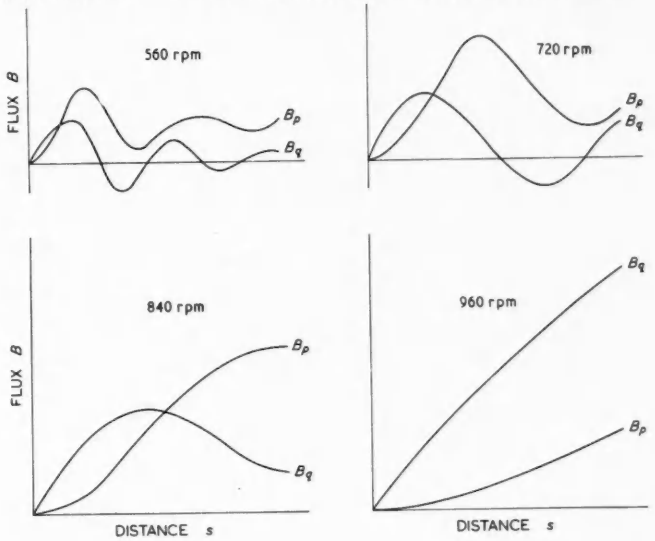

Fig. 8. **Practical results with the Mark II spherical motor, showing flux distribution at various speeds.**

was therefore built with the same rotor diameter but with deeper stator slots, more slots per pole per phase, and thin, high-quality laminations.

The theory developed for spherical motors[10] was verified with this machine by means of a number of search coils located along the length of a stator block. The voltage induced was measured in magnitude and phase relative to the stator current at various speeds and at standstill. The leakage flux was then calculable, and the fluxes B_p and B_q could be separated. A high-frequency supply (300 cps) was used to eliminate as much of the exponential decay as possible. Even so, the effect was considerable, and a much better set of results was subsequently obtained with a third machine, to be described later. These results, shown in Fig. 8, serve to illustrate the effect of the short stator on flux distribution. For a constant current the power output is a maximum at a slip of $1/(n+1)$, where n is the number of poles on a block. There are no excess rotor-copper losses, and this is therefore the slip for maximum efficiency. At this slip the external characteristics of the motor are indistinguishable from those of a conventional machine, except that the power factor is lower. A slip of $1/(n+1)$ should therefore be chosen as representing full-load slip when designing this type of machine.

This is a much higher slip than that permitted in normal machines unless n is very large. However, n cannot be increased indefinitely without increasing leakage and magnetizing current to an intolerable figure. The peak efficiency of the machine is seen to be given by

$$\frac{n}{n+1+(\rho_s/\rho_r)}$$

where ρ_s is the stator surface resistivity whilst the rotor must be capable of dissipating $1/n$th of the output power at full load.

All these factors demand a large value of n. It appears, therefore, that a good machine should be of large diameter to permit a reasonable pole pitch to be obtained with a large value of n, in which case the running speeds will be low. Furthermore, when the stators are rotated to give variable speed, the effective number of poles on a block is changed, being reduced at the higher speed. This must also be taken into account in the design.

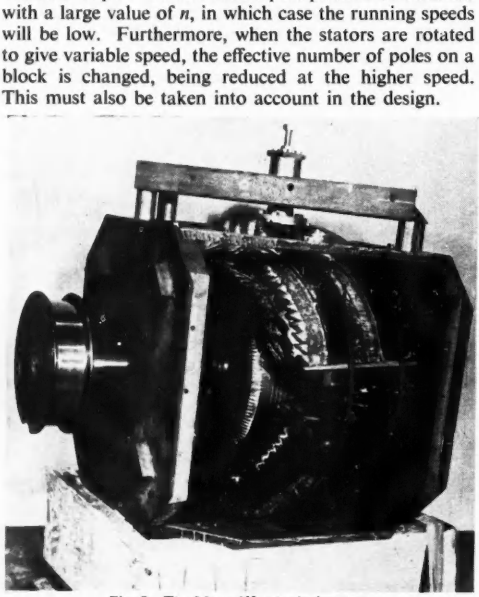

Fig. 9. The Mark III spherical motor.

The second machine had a peak efficiency of 61·5% at a bottom speed of 200 rpm, falling to 46% at a speed of 400 rpm. Its maximum speed range was 5:1.

Both the first and second spherical motors built were designed to permit a number of separate stator blocks to be fitted around the rotor surface. In the experimental machines these blocks could be rotated independently. It is of academic interest to note that, by rotating one block to a different angle from that of another, a "back-to-back" test could be performed on one machine. For a commercial machine, the several stator blocks must be rotated in unison, requiring some form of interconnecting gearing, which might prove to be a disadvantage. A further disadvantage results from the unbalanced magnetic pull exerted by each stator block, necessitating the use of a good thrust bearing on each block, and inevitably increasing the cost of the machine.

The Third Spherical Motor

The most recent machine to be built has been designed to remove the above disadvantages. At the same time, an attempt has been made to obtain optimum performance in the light of the new theory of short-stator machines. The resulting motor is shown in Fig. 9. The rotor of this machine is again 14 in. in diameter, and the stator is made in two blocks, each of which subtends an angle of 140 deg. at the rotor shaft. The two halves of the stator are thus thrusting against one another, rather than against the frame of the machine, and can be rotated as a unit to produce speed variation. By using this two-block type of construction the number of poles on a block can be increased, resulting in better performance, giving the machine shown in Fig. 9 a peak efficiency of 71·5% over a speed range of 375 to 500 rpm, falling to 60% at a top speed of 750 rpm. This machine is to serve as prototype for a much larger motor now being designed.

The new type of motor introduces many interesting possibilities. For example, the angle of the stator field may be servo-controlled to ensure that, at whatever speed is demanded within the available range, the motor is always working at the preferred slip $\sigma = 1/(n+1)$, and therefore at maximum efficiency.

Although no detailed work has been done on a single-phase version of the spherical motor, it is known that the principle of the angled field also applies in this case.

The Phase-Shift Type of Motor

As soon as the new principle had been established, numerous suggestions were put forward as to how electrical, rather than mechanical, orientation might be effected, so as to permit the cylindrical shape of the conventional machine to be retained. A number of these suggestions, which look promising at first sight, do not produce the desired effect. For example, if the stator is made to set up two travelling fields at right angles, variation of the relative magnitudes of the field strengths does not produce an effective speed increase in the rotor, since the only factors which will cause this are a change in pole pitch or a change in frequency. It has also been suggestions, which look promising at first sight, do not thin annular fields which can be twisted mechanically relative to each other around the cylindrical rotor. This type of operation is illustrated by the developed diagram in Fig. 10. In Fig. 10a, the rotor is allowed to travel in the direction of the field YY', and the machine is indistinguishable from a conventional squirrel-cage motor. After sliding the stator rings to the position shown in Fig. 10b, the field direction has certainly been changed

by an angle θ, but the effective pole pitch in the direction of the field has been reduced by a factor of cos θ, and the pole pitch in the direction of rotation of the rotor, and therefore the rotor speed, is unchanged. The most interesting finding, however, is that, if the rotor is constrained to move along the direction XX' instead of YY', then Fig. 10b shows that, as angle θ is varied, the number of poles " seen " by any point on the rotor in one revolution changes, and the speed is varied.

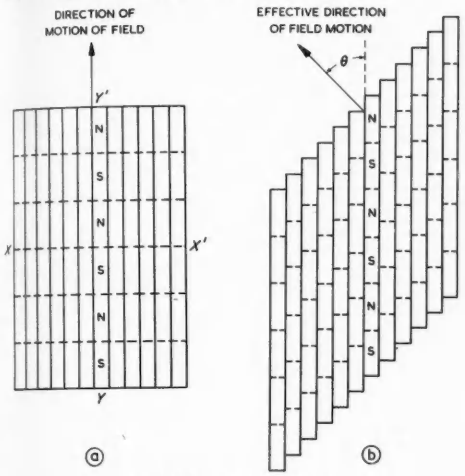

Fig. 10. Principle of the phase-shift motor.

In building a machine of this type it is not proposed to slide stator blocks over each other mechanically, but to effect the same disposition of the poles electrically by using phase-shifting transformers. Blocks of stator laminations can be arranged around the cylindrical rotor periphery, each block carrying windings in slots which are skewed to some preferred angle corresponding with middle speed. Each stator block is magnetically balanced in that it carries an even number of poles. The windings are arranged so that combinations of ampere-turns from direct supply and from supply via a phase-shifter can be used on one block to give the desired proportion of shift to that particular block. The system is better balanced if two phase-shifters giving opposite shifts are employed.

When assembled, the complete stator produces a helical field, the angle of the helix being variable by means of the phase-shifters. A speed range of 3:1 has already been achieved with an experimental motor of this type.

Conclusions

An interesting parallel can be drawn between conventional a.c. commutator motors and these new types of brushes variable-speed induction motor. Commutator motors fall into two classes, i.e., those having brushes whose position around the commutator periphery can be varied mechanically in order to change the speed, and those with fixed brushes fed through a phase-shifter. The variable-speed feature of the spherical motor depends on the ability to rotate the stator mechanically, whilst the phase-shift version relies on electrical phase shift.

An interesting point to note about the new types of motor is that, whereas a spherical motor of reasonable design is a large machine running at low speed, the phase-shift motor promises to have reasonably good performance over the speed range of 1000 to 3000 rpm, and can be of small diameter.

Variable speed is thus achieved in the two cases at the expense of a spherical shape on the one hand, or a pair of phase-shifting transformers on the other. For applications where the power-to-weight ratio of the motor itself is of prime importance, the phase-shift motor may well prove the more successful, since the phase-shifters need not be accommodated in the same place as the required drive. Both types of motor have the advantage that they provide regenerative braking when a lower speed is demanded, since reduction of the angle between field and rotor movement produces a lower synchronous speed. The rotor then travels faster than synchronous speed and becomes an induction generator, returning part of its stored energy to the mains before its speed is reduced to the required value.

It may be said that the new motors fall into the class of machines which achieve variable speed by changing the pole pitch p. They are pole-changing machines with a difference, in that the number of effective poles need not be a whole number which is a multiple of 2. Thus, the second spherical motor had effectively $29\frac{1}{2}$ poles when θ was zero, and this number of poles could be reduced by increasing θ. In these new types of motor, the term " synchronous speed " should therefore be used to indicate the speed of the field in the direction of motion of the rotor, since it is the synchronous speed which can be varied. It is possible to produce a brushless variable-speed induction motor merely by constructing a conventional squirrel-cage machine with a high rotor R/X ratio and controlling the supply voltage. The speed when on load will then be reduced as supply voltage is reduced. Apart from the disadvantage of the variable voltage supply, such machines achieve reduced speed only at the expense of reduced efficiency, since rotor efficiency is given by $(1-\sigma)$. Such machines are perhaps better termed "variable-slip " machines, rather than true variable-speed machines such as the new motors, in which the synchronous speed is variable.

It remains to be seen whether the mechanical layout of the new motors can be designed in such a way that the cost of manufacture is not excessive. However, even if the cost should prove to be high, they will meet a requirement in applications where brushless machines are essential, e.g., where foul chemical atmospheres or explosives are present.

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GERMANY

Problems of Electro-Hydraulic Controls for Machine Tools

By A. DÜRR. (From *Konstruktion*, Vol. 8, No. 5, May 1956, pp. 192-203, 35 illustrations.)

(Concluded from July issue.)

Problems of Positional Controls

The usual types of hydraulic control systems are designed to operate with direct actuation of the valve by tripping devices or cams. The cam control valve is regulated, for instance, by means of a cam rail to five positions, i.e., feed and high-speed motion on both sides of a neutral or stop position. On either side of the neutral position the movement is positively and reliably controlled by the cams. Only the travel through the stop position into the other direction, i.e., the change from high speed or feed on one side to feed or high speed on the other, is obtained indirectly by means of an auxiliary valve circuit. Cams on the near side of the table actuate an additional valve unit which controls approach, clamping, release, and removal operations in accordance with table positions.

These direct positional controls operate with a high degree of reliability and have contributed greatly to the success of hydraulic equipment. Nevertheless, they are now being discarded in many instances, because there are difficulties in supplying pressure oil to hydraulic units fixed at certain positions, and because control possibilities are restricted and do not fulfil present demands for greater rapidity, efficiency, accuracy, and comfort in individual operations or automation processes.

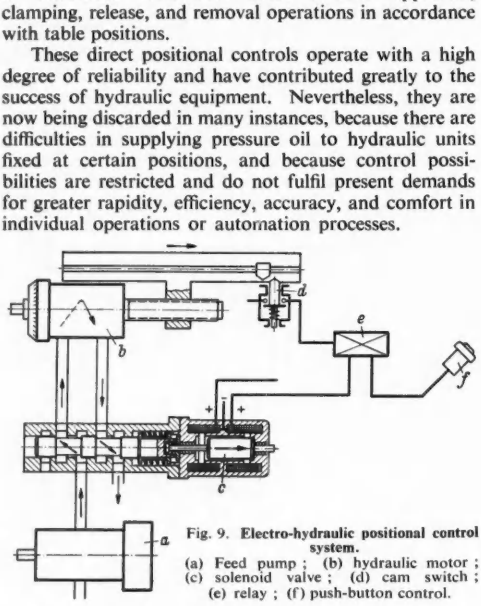


Fig. 9. **Electro-hydraulic positional control system.**
(a) Feed pump ; (b) hydraulic motor ; (c) solenoid valve ; (d) cam switch ; (e) relay ; (f) push-button control.

In contrast with these systems, the electro-hydraulic positional control system is frequently designed for indirect operation, as shown, for instance, in the schematic set-up in Fig. 9. The cams deliver a mechanical impulse to the cam switch *d*, which then transmits an electrical pulse to a coil in the relay *e*. The relay opens the circuit to the solenoid valve *c*, the d.c. magnet is de-energized, and the solenoid valve is able to revert from the position indicated in the figure to its neutral or stop position.

Where difficult conditions are imposed, e.g., large oil quantities and high hydraulic pressures, the magnet, instead of actuating the main control valve directly, is made to operate a pilot valve which regulates the supply of pressure oil to the main valve. The arrangement in Fig. 9 has four indirect processes operating in succession; with a pilot valve, the system has five indirect operations to perform before the flow of pressure oil is regulated. Consequently, the requirements for correct design, manufacturing tolerances, and comprehensive tests will be more exacting in this case.

In addition to the cam switches fitted at the most suitable positions on the machine, some form of manual control is required. From handwheels, levers, and hand cranks, electro-hydraulics gradually incorporated push-button controls, with one or more easily transportable units. A single-wire impulse control system was developed in which all control devices (push-buttons, cam switches, rotary switches, etc.) are used only to deliver impulses, and are connected by a single wire to the actuating units, the equipment being specially designed for efficient and foolproof operation. Each push-button has its indicating light for every motion, direction, and speed, and the circuitry is such that each process begins only when the corresponding push-button has been operated.

Cam Control Systems

Fig. 10 shows a four-terminal cam switch with cams for " stop ", " high speed " (*E*), " feed " (*V*), and " fine feed " (*L*), a characteristic signal or train of pulses being assigned to each cam or switch. The limit switch of the piston rod towards the left or of the piston towards the right does not necessarily have to be actuated in these control operations.

Different conditions occur if, for instance, a longitudinal motion is followed by a transverse motion, as in plane-milling. To achieve this, an additional piston and valve unit is provided for transverse motion control at the rear end of the operating head. In this case, the fixed end-stops must be contacted, since the hydraulic piston *a* (Fig. 10) has no absolutely fixed stopping position unless the moving part is hydraulically locked in a complicated manner. Nevertheless, it is not always possible to reduce the number of signal impulses to less than four.

For instance, at the front end-stop, owing to the pressure rise behind the piston, a change-over to transverse motion is effected. With a blunt tool, however, this transverse motion controlled by pressure might begin ahead of the stop. The result would then be a transverse pull at the wrong position, a rejection of the workpiece, and the risk of fracture of the tool. If this unit operates in a transfer system, all the following stations would be in danger, owing to this defective operation. Therefore, besides the pressure-controlled change-over at the stop, there should also be a positional control impulse to report that the manoeuvre is performed or completed. In practice, this impulse would then have to be delivered just when the stop is contacted, and this is not an easy adjustment with a separately arranged cam switch. The clearing signal is therefore delivered a small distance ahead of the stop.

Improved conditions are obtained with a hydro-mechanical drive in which a screw spindle serves to ensure

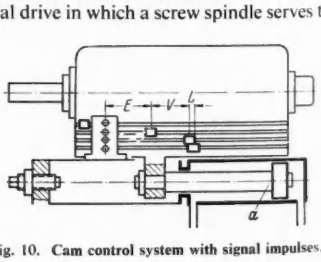


Fig. 10. **Cam control system with signal impulses.**

positive stopping in a simple manner at one or more required positions, for various phases in the working cycle. The problem of positioning with or without a stop has been the subject of many investigations. With either arrangement, the accuracy attainable depends on various factors and primarily on the approach speed. If no stop is used, this speed must be reduced considerably, shortly before the stop position, to obtain accurate operation. As a rule, in such cases the system is adjusted for "slow" or "fine feed" at about 10 mm/min and attains an accuracy of the order of 2 or 3 microns, a value which is very frequently well below that attainable with a stop. It should be borne in mind that, with a stop, considerable elastic deformations occur, whereas when operating without a stop the impulse is produced directly by the moving part of the machine.

Cam Control with Neutral Impulses

In order to reduce the number of signal impulses, cam controls with "neutral" impulses have been developed. Fig. 11 shows a system in which only one series of cams and a single-terminal cam switch are required. This does not solve, however, the problem of a simple and rapid adjustment of the working cycle; in fact, there are considerable difficulties if it is necessary to intervene manually at any phase of the cycle. A shift of one switching stage would, for instance, vitiate all the impulses; therefore, extensive precautions are taken, and neutralizing impulses are used to "lock" the control cycle to a predetermined datum position and to prevent any external influences. The system also incorporates plug-in programming arrangements. However, if the programme to be carried out is constant or rarely varied, the additional outlay is not justified.

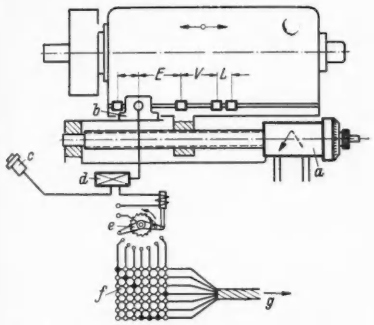


Fig. 11. **Cam control system with neutral impulses.**
(a) Hydraulic motor ; (b) cam switch ; (c) push-button control ; (d) relay ; (e) rotary step switch ; (f) multiple-plug type of programming unit ; (g) cable to actuating devices.

For machines required for various operating cycles a combined control system with signal impulses and neutral phasing impulses is particularly useful. The machine may have, for instance, two six-terminal cam switches, for longitudinal and vertical motion, respectively. Each switch has six sets of cams for high speed, feed, and stop in two directions of motion (left and right, or up and down). These signal impulses are individually adjustable to the required settings. The multiple-plug type of programming panel permits only those switches to be energized which are required in a particular sequence, whereas the others remain inoperative when passed over in that phase of the cycle. As in the previous arrangement in Fig. 10, the system includes a rotary-type step switch and a relay, to which the push-button control for manual

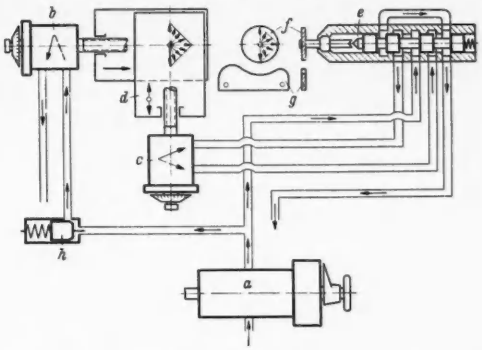


Fig. 12. **Hydro-mechanical copying control system.**

adjustments is also connected. The system provides maximum security in operation. The neutral pulses are delivered at the datum points, i.e., at the (intermediate) stop positions of the longitudinal and vertical control units and pass through the relay to the programming unit, so that at these positions one cycle can be completed and a new one commenced with different speeds, feed rates, and directions. This control system has been successfully applied to many types of automatic milling machines, lathes, and drilling machines.

The problem of cams is not, of course, eliminated in the above systems. In some automatic machines, the number of cam settings required would be such that it would offset some of the advantages of automation, in spite of improved programming and storage devices ; this has made it necessary to seek other solutions. For instance, a co-ordinate drilling machine has been developed with camless positional controls incorporated in drum-type contactor units, by means of which any required distance can be controlled with an accuracy of 0·01 mm. After the appropriate adjustments have been made, the drum instructions are included in the programming sequence. Other types of controls operating without cams have also been produced, for instance with counters, photoelectric impulses, magnetic tape, etc. ; however, they do not offer the simplicity, reliability, and low cost of a cam control system. Further research in this direction is required, as conventional methods are now approaching their limits of efficacy.

Problems of Copying Controls

Important problems present themselves in the development of copying controls and feeler mechanisms for machine tools. Two systems which have been successfully proved in practice are briefly described in the following.

Fig. 12 shows a hydro-mechanical copying control system, in which the servo-valve *e* is operated directly by a feeler with a roller *f* moving on the master or template *g*. In the valve position shown, the pump *a* can deliver a predetermined quantity of oil to the servo-valve and through the open port to the hydraulic motor *b*. The feeler first moves transversely downwards onto the template, and during this contacting motion the servo-valve piston is shifted towards the right and thereby closes the outflow to the transverse hydraulic motor *c*. The oil from the pump *a* then seeks to find a different path; it acts on the relief valve *h*, overcomes its spring pressure, and flows into the longitudinal hydraulic motor *b*; this operates the longitudinal motion of the table *d* towards the right. If, in a rising portion of the

template, the pressure on the feeler becomes higher, the servo-valve allows the oil to flow through the other line to the transverse hydraulic motor *c*. The relief valve has again closed the path to the longitudinal hydraulic motor, and in this case the motion occurring is then vertically upwards. Apart from these three specific directions of motion, however, all intermediate resulting motions are possible, as indicated by the arrows in the figure. This arrangement operating through direct control of the flow of pressure oil is extremely reliable. The four lines to the feeler-operated servo-valve are, however, a problem, as this valve is frequently at a considerable distance from the pump aggregate, and in most cases flexible hose or telescopic supply lines are necessary.

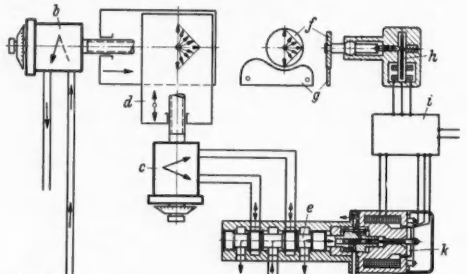


Fig. 13. **Copying system with hydraulic and electronic controls.** (a) Feed pump ; (b) hydraulic motor for longitudinal motion ; (c) hydraulic motor for transverse motion ; (d) table ; (e) servo-valve with control ports ; (f) feeler and roller ; (g) template ; (h) inductive-type transducer ; (i) electronic amplifier ; (k) moving coil ; (l) relief valve.

The combined electronic and hydraulic copying control system shown in Fig. 13 has the same main hydraulic system as in the above example. However, the servo-valve is now operated indirectly; the motions of the feeler *f* are followed by an inductive-type transducer *h* which transmits them to an electronic amplifier *i*. The output impulses from the latter, which are proportional to the input, are then fed into a moving coil *k*, which is situated in the air-gap of a d.c. magnet. A small auxiliary servo-valve is connected to the moving coil. By means of this valve and its piston, the displacements of the moving coil are transmitted to the main servo-valve *e* by regulating the oil supply to the servo-piston. There are, therefore, four or five indirect processes in this control arrangement. The electronic amplifier enables a high ratio of amplification to be obtained without increasing the pressure of the feeler against the template. Obviously, this system permits the feeler and its transducer unit to be placed at any distance from the machine, and an electric cable is more easily movable than four heavy pressure-oil hose lines. A further important advantage is that the copying servo-valve is in this case built integrally with the pump unit at the position of the usual solenoid valve for transverse motion. The drawbacks in this equipment are the higher costs and the more delicate electronic components. As in the case of positional controls, the trend with copying controls is also developing from directly operating to indirectly operating control units—undoubtedly a step in the right direction.

The performance of the two systems differs mainly with respect to the accuracy attainable. For instance, with a hydro-mechanical system incorporating a feeler and a servo-valve, copying accuracy is 0·1 mm when the flow through the valve is varied from 50 litres/min to zero, in either direction, with a neutral zone of 0·02 mm over which the change in direction takes place. With the electronically operated valve, the accuracy is ten times greater. To obtain accuracies of this order, the hydro-mechanical system would have to operate with much smaller flow quantities, i.e., from 10 litres/min to zero, involving the use of specially designed valves, and even then the accuracy would still be only about 50% of that of the electro-hydraulic system. Moreover, the object, as a rule, is not only to have a copying motion, but to include it in an automation process ; therefore, preference will tend to be given to the electro-hydraulic unit.

Response Times and Regulating Constants

It is of interest to consider the problems of regulating times and constants. It is frequently and quite erroneously asserted that hydraulic elements have an extremely slow response and follow electrical impulses only with a considerable time lag. Such statements require experimental verification. Oscillograms of an electro-hydraulic feed control unit and a hydraulic motor show, for instance, that the impulse for high-speed motion is followed by the pump unit in 0·07 sec and the hydraulic motor is then accelerated from 0 to 1400 rpm in another 0·23 sec. The reverse process from 1400 rpm to zero is somewhat more rapid, i.e., in 0·18 sec.

In tests of an electro-hydraulic valve control, six-channel recordings were taken, with time markings, curves of solenoid-valve response, valve displacement, operating-pressure variation, and transient response of the hydraulic motor. The solenoid valve responded to the relay signal in 0·015 sec, the control valve started operating in 0·07 sec, and reached its full stroke of 6 mm in 0·24 sec. In the meantime, the oil pressure began to rise in 0·11 sec and the hydraulic motor then accelerated from zero to 1400 rpm in 0·19 sec ; after a slight overshoot it reached the steady condition of 1400 rpm in 0·29 sec. Further oscillograms of this type were obtained with a hydraulic copying system incorporating electronic elements. The hydraulic motor in this instance reached 500 rpm (for a feed rate of 1000 mm/min) 0·055 sec after the signal was emitted by the transducer unit, and its acceleration from zero to this speed took only about 0·015 sec. The upper portion of the curve up to 1400 rpm was similar to that of the motor in the valve control of the previous test.

From these results, it can be seen that hydraulic systems operate extremely rapidly and follow the electrical impulses with practically no time lag, the reason being that their drive components have very small inertia masses ; the moment of inertia of the hydraulic motor is only 10% of that of an equally powerful three-phase motor, and is even a much smaller percentage of that of an electromagnetic coupling for the same value of torque. The hydraulic motor is not only superior to the electric motor as regards dimensions, but its great advantage is that it is adjustable to any desired value of speed from zero to maximum, in both directions ; also, it can, if necessary, operate as slowly as clockwork mechanisms.

In conclusion, it may be said that the advances obtainable with electro-hydraulics are of far-reaching significance and undoubtedly will enable many machines to be placed on an entirely new level of development, as regards their efficiency, accuracy, and economy of performance. Electro-hydraulics can thus be an important link in the chain of production processes.

Automatic Control of Hobbing Machines by Gear Gauges

By R. C. Miles. (From *Electronics*, Vol. 29, No. 7, July 1956, pp. 140–144, 8 illustrations.)

In the electronically controlled hobbing-machine installation described in this article, probes, attached to cores of linear variable-differential transformers, measure the pitch diameter and root fillet of automobile transmission gears, generating signals for logic and control memory circuits which automatically adjust the depth setting of the hobbing cutter or which shift the cutter laterally to replace dull cutting surfaces.

The electronically controlled hobbing-machine installation in the automobile transmission plant described in this article involves six-spindle gear-cutting machines, each of which has six essentially independent hobbing cutters mounted on a rotating platform. Each spindle discharges a completed gear as it passes a common discharge point. A single control unit measures and sorts the gears from all six spindles, controlling the spindles individually by six sets of control circuits.

Other installations of this electronic control have been made on single-spindle hobbers. For simplicity, the control equipment is described in terms of a typical single-spindle installation.

Inspection Requirements

Each gear is automatically inspected as it comes from the hobber. This inspection includes measurement of pitch diameter and root-fillet build-up, the latter being indicative of the extent of hob wear. Gears are sorted physically as being acceptable or unacceptable, and appropriate control signals are supplied to the hobbing machine. These control signals include demands for adjustments to correct pitch-diameter errors observed in the gears, shift the hobbing cutter laterally as a means of replacing dull cutting surfaces, and shut down the hobbing machine when attempts to adjust it prove unsuccessful.

In the interests of good hobbing-machine control, measurements on the gears employ two sets of tolerances for each gear characteristic of interest. One set of tolerances, symmetrical about the nominal dimensions, is used principally as the basis for physical sorting of the gears. A narrower set of tolerances, also symmetrical, provides the basis for controlling the hobbing machine to limits which are somewhat smaller than the allowable manufacturing tolerances on the gears. By means of these two sets of tolerances, production of gears exceeding the manufacturing tolerances is kept to an absolute minimum.

Control Requirements

Control of the hobbing machine, as regards both pitch-diameter adjustment and automatic hob shift, is in fixed increments. Consequently, the electronic control equipment is required only to operate the appropriate set of relay contacts in order to energize the adjustment mechanisms which are an integral part of the machine.

Although the control equipment is capable of detecting minute differences in gear dimensions, random variations in the hobbing-machine output can result in individual gears which do not truly represent the need for hobbing-machine adjustment. Consequently, the hobbing-machine control signals are based on trends rather than on individual gears.

In the case of pitch-diameter errors, three successive gears must fall outside the narrow tolerance limits before the control equipment calls for readjustment of the hobbing machine. In the case of apparent hob wear, a hob-shift signal results each time two successive gears show root-fillet build-up in excess of the narrow tolerance limits. If a single small shift does not correct the root-fillet build-up, additional shifts are made after each pair of gears with excessive build-up.

After calling for hobbing-machine readjustment, the control equipment continues to count successive gears with the same type of error. If the count reaches ten, without at least one gear falling within the narrow tolerance limits, it is assumed that the hobbing machine requires human attention. The control equipment then opens a pair of contacts which remove operating power from the hobber.

Gears are automatically fed to two gauging stations at which pitch diameter and root-fillet build-up are measured successively. After leaving the second gauging station, the gear passes through one of three sorting chutes, depending on actual gear dimensions as compared with the production tolerance limits.

Fig. 1 shows enlarged cross-sections of gear-tooth spaces, illustrating how the gauging probes make physical contact with the gear. The conical measuring probe contacts the gear at the pitch circle, and any variations from nominal pitch diameter are apparent as a displacement of the measuring probe along the radius of the gear.

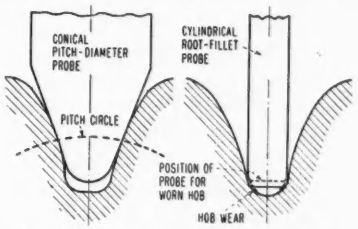


Fig. 1. Measuring gear teeth by means of probes.

The method used to detect hob wear is also illustrated in Fig. 1. The solid lines show the shape of the gear-tooth space and the position of the cylindrical measuring probe when the gear has been cut with a sharp hob. When the hob begins to wear, the effects are evident as growth of the root fillet of the gears. The broken lines illustrate such growth, and show the resulting displacement of the root-fillet measuring probe.

The mechanical portion of the control equipment includes a set of cam-operated switches which provide the necessary sequencing and timing signals for the electronic circuits.

Gauging Heads

The electronic measuring system is shown schematically in Fig. 2. The gauging transducers are a pair of linear variable-differential transformers, one each for the pitch-diameter and root-fillet measurements.

Each differential transformer consists of a single primary winding and a pair of secondaries connected in opposition and symmetrically disposed about the primary. A movable magnetic core, mechanically connected to the gauging probe, varies the coupling between the primary and the two secondaries. Thus, when the primary is excited, the net output voltage from the two secondaries is proportional to the distance between the actual core

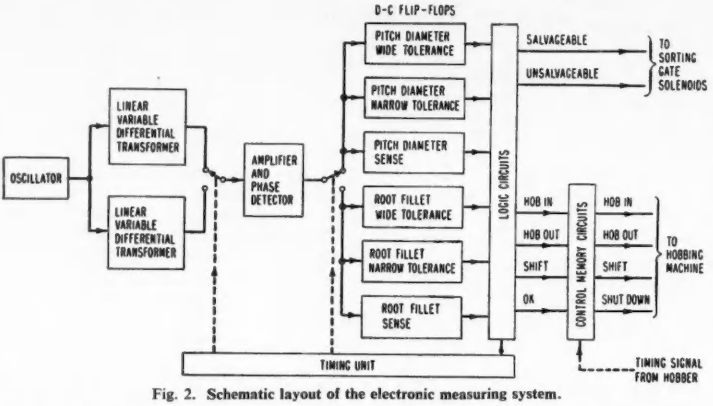


Fig. 2. Schematic layout of the electronic measuring system.

position and its null position. The phase of the output voltage is a function of the direction of core movement from null. The result is a null-type measuring system with excellent linearity, good sensitivity, and freedom from moving contacts. Typical units have sensitivities of the order of 1 mV per 0·001 in. per volt excitation.

Measuring Circuits

The two differential transformers are driven by a common oscillator, their outputs being applied, through relay contacts controlled by the timing unit, to a common amplifier and phase detector. The oscillator is a bridge-stabilized type, supplying a 2000-cps drive at about 3 V to the differential transformer primaries. The amplifier and phase-detector circuits are conventional, including the use of negative feedback in the amplifier. The primary purpose of this feedback is to stabilize operation against such factors as power-supply variations and tube-characteristic changes.

Although gear-sorting and hobbing-machine control operations are both of an incremental nature, the measuring circuits operate on an analogue basis. The reasons for this include the advantages obtained from the use of the differential transformers, which are basically analogue devices, and the ease with which adjustable tolerances can be obtained in an analogue system, as compared with a digital system.

The conversion from analogue to digital measurement information takes place in a set of six direct-coupled flip-flops following the amplifier and phase detector. Four tolerance flip-flops are driven by the amplifier, while two sense flip-flops are driven by the phase detector. In all cases, relay switching is employed to activate the particular flip-flops corresponding to the gear characteristic being measured.

The four tolerance flip-flops each include a sensitivity control calibrated directly in thousandths of an inch tolerance. This facilitates adjustment of the equipment, even by inexperienced operators.

Logic Circuits

Pitch-diameter and root-fillet measurements are made sequentially, but logical decisions as to gear sorting and hobber control must be based on both measurements. Consequently, the three logic relays associated with pitch-diameter measurement include electrical locking circuits. Lock-up is automatic at the time when pitch diameter is measured; unlocking is controlled by the timing unit at the end of the operating cycle of the control equipment.

With the aid of the wide tolerance and sense flip-flops, gears are physically rejected if they fall outside the manufacturing tolerance limits. Rejected gears are further segregated as either salvageable or unsalvageable. A salvageable gear is one which has been left with its pitch diameter and/or root fillet above manufacturing tolerance limits. An unsalvageable gear is one which has been left with its pitch diameter below manufacturing tolerance limits: there is no significance to a gear whose root-fillet build-up is excessively small.

From the standpoint of hobbing-machine control, logic requirements are somewhat more complex. If the hobbing machine is taking a cut which is either too deep or too shallow, the gears will have incorrect pitch diameter, and readjustment of the hob in-out mechanism is indicated. Unfortunately, such a condition also has the basic symptoms of excessive fillet build-up resulting from wear of the hob cutting surfaces.

Similarly, actual wear of the hob affects the pitch diameter of the gears to some extent. However, incorrect adjustment of the hob in-out mechanism has effects of equal magnitude on both pitch diameter and root-fillet build-up, while hob wear affects root-fillet build-up by several times the effect on pitch diameter.

Consequently, the logic circuits classify each gear according to the magnitude and sense of its departure from nominal values of both pitch diameter and root fillet.

Control Memory Circuits

There are two reasons for using control memory circuits rather than controlling the hobbing machine directly from the logic circuits. Firstly, the control memory circuits permit controlling the hobbing machine from observed trends in the gears, rather than supplying control signals based on measurement of a single gear; and secondly, some sort of control-signal memory is required because the hobbing machine is capable of accepting adjustment signals only during a specific portion of its cycle. Thus, the logic information must be stored in some manner, at least until the hobber is capable of responding to a demand for adjustment. The control memory circuits thus perform the dual function of determining trends and storing control signals until they can be transmitted to the hobber.

The control memory circuits mainly involve a set of three stepping relays. Each of these relays has ten positions in addition to a zero position, and each relay corresponds to one of the three possible hobbing-machine adjustments, i.e., " hob in ", " hob out ", and " shift ".

At the time each gear is being measured for root-fillet build-up, the timing unit supplies a register pulse to the logic circuits. Depending on the positions of the six flip-flop relays, this register pulse then appears on one of four buses to the control memory circuits.

The " hob in ", " hob out ", and " shift " buses each operate one of the three stepping relays, causing the relay to advance one step each time a register signal appears on the associated bus. A signal on an " O.K." bus, on the

other hand, resets all three stepping relays to their zero positions. Furthermore, each time one of the stepping relays steps forward, it automatically resets to the zero position either of the other two relays which may have previously advanced off zero. Consequently, each stepping relay counts only the successive gears showing the need of the related hobbing-machine adjustment.

Each time the hobbing-machine cycle reaches a point such that it can accept an adjustment signal, an interrogating signal is supplied from the hobbing machine to the stepping-relay contacts. If either the " hob in " or " hob out " stepping relay has counted three successive gears, or if the " shift " relay has counted two successive gears, the interrogating signal passes through the stepping-relay contacts to an associated power relay. Operation of the power relay then supplies the desired adjustment signal to the hobbing machine.

If one of the stepping relays counts ten successive gears, the interrogating pulse operates a shut-down relay, which removes operating power from the hobber and locks up until it is manually reset.

Additional Features

The timing unit with its six cam-operated switches is a separate sub-assembly, chain-driven from the main camshaft of the mechanical handling apparatus. For ease in setting up the timing relationships, the six switch cams are on separate splined sections of the camshaft.

Of the six switches, two accomplish the transfer of the amplifier-phase detector between pitch-diameter and root-fillet measuring functions, two provide register signals to actuate the sorting-gate solenoids and the control memory relays through the logic circuits, and two reset the locking circuits of the sorting solenoids and the logic relays.

In addition, there are two switches which operate in response to the actual presence of a gear in the mechanical handling portion of the equipment. These prevent false actuation of the control memory circuits during operating cycles in which no gear is actually being measured. Indicator lights give the hobbing-machine operator a visual indication of the classification of each gear as it is inspected.

JAPAN

Deburring of Aluminium Gears by Electrolytic Polishing

By M. Naruse and A. Nannichi. (From *The Technology Reports of the Tôhoku University*, Vol. 22, No. 2, 1956, pp. 225–233, 11 illustrations.)

After gear-cutting operations, burrs and flashes are often found on the faces and flanks, and the usual procedure is to remove them one by one by mechanical or manual methods. To eliminate the disadvantages of such procedures, successful experiments were conducted with the object of deburring gears by electrolytic polishing and, at the same time, to produce a good overall surface finish.

The gears used in these experiments were made from 99·6% aluminium plate of 27·5 mm thickness by pressing in two stages, as a result of which burrs were found on the edges of each tooth. The gears have 20 teeth, a module of 0·58, a pressure angle of 15 deg., a pitch-circle radius of 11·62 mm, and an outside diameter of 21·28 mm.

In the electrolytic polishing method used, the electrolyte consisted of a solution of phosphoric acid, with a specific gravity of about 1·4, contained in a glass beaker of 100 cc capacity. The source of current was a d.c. generator, with an output of 120 V, 10 to 12 A, and provision was made for controlling the current to any desired amount by means of two rheostats, and for measuring both voltage and amperage. The experimental gears were suspended in the electrolyte by an insulated lead, parallel to and 3 cm from a 99·98% aluminium plate, 4·5 × 6 × 0·15 cm, the gear being the anode and the plate the cathode. Except in a number of special cases, the initial temperature of the electrolyte was normal room temperature, and was permitted to rise during electrolytic polishing operations.

In this deburring by electrolytic polishing, it was observed that the action of the electrolyte on the edges of each tooth to which burrs are attached is greater than on most of the flat surfaces, the ridged portion having a tendency to become rounded. Moreover, the dissolution of the burrs themselves is more rapid than the edges of the teeth. With further application of the electrolytic polishing process, the minute proportion of burrs remaining dissolves at approximately the same rate as most of the flat surfaces, becoming slightly rounded and finally disappearing without leaving a mark.

It was found that, as soon as current was passed through the electrolyte, the voltage rose abruptly until the oxide film on the surface of the aluminium was disrupted. The voltage then started to drop, at first rapidly but later at a diminishing rate, while the current showed a tendency to rise. Additional experiments, to determine optimum current conditions, produced the following results :—

(a) An experimental gear was treated at from 50 to 150 mA for 30 min, but though a smooth electrolytically polished surface was produced, very little deburring was noted.

(b) With a current of 300 mA applied for from 45 to 50 min, burrs were removed completely, and the surface finish of the gear was very smooth ; furthermore, the edges of each tooth were only insignificantly rounded off. At the end of the operation, the gear lost from 5 to 8% of its mass, compared with 7% lost through mechanical polishing.

(c) With the object of shortening the electrolytic polishing operation, experiments were conducted with currents of 1·0, 1·5, and 2·0 A, for 30, 20, and 15 min respectively. In all cases, the gears were deburred enough to show no burr marks, and the respective masses lost were 6 to 8, 7 to 8, and 8 to 10%. In these tests, the temperature of the electrolyte rose to between 50 and 60° C, and the voltage dropped finally to between 4 and 6 V.

(d) Attempts to shorten the operation still further by using currents of between 2·3 and 2·5 A were not successful, as microscopic ripples and streaks sometimes appeared on the surface.

GERMANY

The M.A.N. "M-Process" of Combustion for Diesel Engines

By J. S. MEURER. (From *V.D.I.-Zeitschrift*, Vol. 98, No. 13, May 1, 1956, pp. 595-599, 9 illustrations.)

Noise and soot formation in connection with high-speed diesel-engine combustion has been attributed exclusively to incomplete mechanical mixing of the fuel and air, but it has now been established that this is not the true picture. To satisfy the conflicting requirements of mixture formation and chemical reaction processes, a new set of rules has been developed for the combustion process in diesel cylinders, from the application of which the M-combustion system described in this article was derived.

IT is understandable that, in the past, attention was concentrated on the problem of obtaining a sufficiently rapid mixing of fuel and air, since in high-speed diesel engines the time allowed for mixture formation at a given speed is only about one sixth of that available in engines with external carburation systems. The ideal mixture was considered to be that which would provide the necessary quantity of combustion air in the immediate vicinity of each minute fuel droplet at the onset of combustion, and endeavours were made to improve mixture formation by trying out new combinations of atomization, fuel distribution, and air motion in the combustion chamber. Combustion noise and soot deposition were regarded exclusively as results of imperfect mechanical mixing. It was only when it became possible to determine the quality of mixture formation quantitatively that positive proof was obtained that improvements in mixture formation do not eliminate the above defects in diesel-engine combustion. In fact, it has become evident that the conventional type of mixture formation is associated with chemical phenomena which have an adverse effect on the combustion process.

An essential difference in the mixing processes of diesel engines and petrol engines is that in the diesel engine a considerable difference in temperature exists between the two components of the mixture, i.e., fuel and air. Temperature has a predominant influence on the development of chemical processes, as is known from the equation of Arrheniusus. If liquid fuel is mixed with very hot air in a diesel engine, the high temperature acts on the structure of the fuel. Under these conditions, the peculiar feature of the diesel fuel becomes apparent, i.e., its molecules, particularly when in the state of a heterogeneous mixture, tend to form peroxides with spontaneous partial reactions which lead to dissociation or decomposition phenomena. These reactions not only facilitate self-ignition but also, by splitting off fragments rich in hydrogen, allow an increasingly carbon-enriched residue of molecules to be generated. This carbon residue is chemically inert and finally appears as soot in the exhaust gas. Owing to the dehydrogenation, i.e., the stripping of its hydrogen atoms, the molecule is deprived of a catalyst provided by nature, since the carbon reaction receives a very desirable acceleration through the end-product of the hydrogen reaction, but only when the latter reaction occurs in the molecular vicinity. The more the temperature rises in the course of combustion, the more rapidly the decomposition reactions take place; these can no longer be slowed down but grow exponentially and bring about a complete dissociation of the molecule. The usual character of the reaction in the diesel engine is obtained in this way, i.e., at first a very high reaction velocity, associated with knock, and towards the end a slow post-combustion of the inert carbon.

These kinetic reactions are the barrier to mixture formation in the diesel engine. Every improvement in the mixing of the liquid fuel with the hot air of the combustion chamber, besides giving rise to self-ignition, increases the proportion of the fuel which is subjected to the decomposition process. The initial velocity of the reaction is increased, but the quantity of inert carbon also becomes greater.

These diesel-engine phenomena are easily followed in spectrographic investigations. Spectrography, however, also shows, for instance, that the combustion of gas oils in a burner is not associated with a molecular decomposition of this kind and of such importance. The burner operates without any soot formation, even with very rich mixtures. In this case, the character of the reaction in the burner flame is altered considerably by slow preoxidation. Furthermore, it is known that the manner in which the fuel-air mixture is generated has a decisive influence on the character of the ignition and the combustion process.

From the above, a series of conclusions can be derived regarding mixture-formation methods. The detrimental results of the decomposition process, which are inevitable with self-ignition, can be eliminated if the following three rules are observed:—

(1) Only a minimum portion of the fuel should be subjected to self-ignition.
(2) The main quantity of fuel should be given the opportunity of evaporating and preoxidizing slowly, without overheating.
(3) The evaporated fuel should be mixed as far as possible in its original condition with hot air swirling in the chamber; the mixing of successive layers of fuel vapour should be so rapid that, before the occurrence of ignition, an approximately correct (stoichiometric) ratio is obtained for the mixture, which can then be ignited externally, i.e., by contact with ignition nuclei obtained from the small portion of fuel mentioned in (1) above.

Since these requirements cannot be fulfilled by the usual mixture-forming processes, a new mixing and combustion sequence has had to be developed. First of all, the small portion of air subjected to self-ignition can be atomized and mixed with hot air in the same manner as the total amount of fuel treated previously in diesel engines. In the meantime, the main fuel quantity, which has been sprayed on the combustion-chamber walls, is heated by air-swirl passing over it and evaporated before taking part in the mixing process. This evaporation, moreover, will have the advantage of reducing considerably the time required for mixing, i.e., to about one sixth of that taken by the usual mechanical mixture-forming process. Therefore, the fuel vapour will still consist of non-dissociated (or only slightly dissociated) molecules when it is ignited by contact with ignition centres from the small self-ignited portion. The rate at which this process will occur can be as high as that associated with the permissible rate of pressure rise. The rate of evaporation will be determined by the temperature difference between the gas and the wall, which increases with time, and by increasing gas radiation.

Fuels with a high ignition point will also provide more time for the mixing process before tending towards ignition. Thus, the mixture will be burned as far as

possible before self-ignition occurs. Because of combustion noise and soot, self-ignition of the main mixture should be avoided, as previously stated. The features of the M-process developed on the above basis by M.A.N. in Germany will now be considered.

Basic Features of the M-Process

The piston is designed with a hemispherical cavity forming the combustion chamber. The obliquely directed injector sprays fuel around the combustion-chamber wall in the form of a thin film of liquid, and only a minimum portion becomes atomized in the air space. The edge of the cavity has a step on one side of the injector and this permits the creation of a powerful air-swirl which assists in the spreading of the liquid film. Under full-load conditions, this film has a thickness of about 12 microns only. The fuel, therefore, instead of being directed into the midst of the high-temperature air, is heated only to the required extent on the combustion-chamber wall, so that the quantity of oxygen supplied to it is, in effect, "thermally regulated". Thus, there is no possibility of spontaneous combustion of uncontrolled quantities of fuel. As there is only a short gap between the nozzle orifice and the combustion-chamber wall, only a small portion of the fuel can separate from the main jet. This small quantity is atomized and dispersed, and undergoes an initial diesel-engine type of self-ignition process in the air space of the combustion chamber.

The fuel adhering to the wall heats up gradually and begins to evaporate, the rate of evaporation depending on the difference between wall temperature and gas temperature, as well as on gas radiation, both of which increase during the process. As each new layer of fuel vapour is formed, it mixes with the hot gas, and this mixing occurs very rapidly, owing to the vaporized form of the fuel and the high air velocity. The evaporating portions of the fuel have suffered no dissociation, or only very little, and therefore form a mixture which, precisely because of its long period of gradual induction, will not reach a state of self-ignition but which will burn through external ignition, produced by the glowing carbon particles from the initial self-ignited portion of the fuel.*

The sequence of operations in the M-process can be summarized as follows:—

About 5% of the fuel is (1) sprayed into the air space, (2) mixed with hot air while in liquid form, (3) evaporated at high temperature in the presence of oxygen, so that (4) self-ignition of uncontrollable amounts of fuel occurs (with low ignition temperature and a high rate of oxidation), the fuel dissociating into carbon and hydrogen, and (5) combustion takes place with an initially high reaction velocity, which rapidly decreases towards the end of combustion.

The main fuel quantity (95%) is (1) sprayed in liquid form on the wall, (2) evaporated at low temperature (slow preoxidation and thermal regulation of the oxygen supply), so that (3) the fuel vapour mixes with hot air, and (4) external ignition is obtained by means of the self-ignited particles produced from the 5% of the fuel previously introduced, so that (5) combustion takes place before self-ignition conditions are reached.

In the M-process, mixture formation occurs *after* evaporation, for 95% of the fuel, whereas mixture occurs *before* evaporation in the conventional diesel engine. In this connection, the piston wall in the M-process performs a function analogous with that of a carburettor in a petrol engine, acting as an intermittently operating surface-type carburettor which vaporizes even those fuels with a high distillation point, working under high pressure and temperature conditions. As the mixture is produced immediately before it is burned, it is exposed to the influences of pressure and temperature during short periods only, so that knock phenomena are avoided.

All the engines so far built with the M-combustion system (with cylinder bores from 85 to 145 mm) show remarkably quiet development of combustion through the entire range of running speeds and loads, including idling and cold starting. This feature is maintained, within wide limits, irrespective of the type of fuel or its ignition quality. This quiet running is not obtained at the expense of an increase in fuel consumption or a reduction in

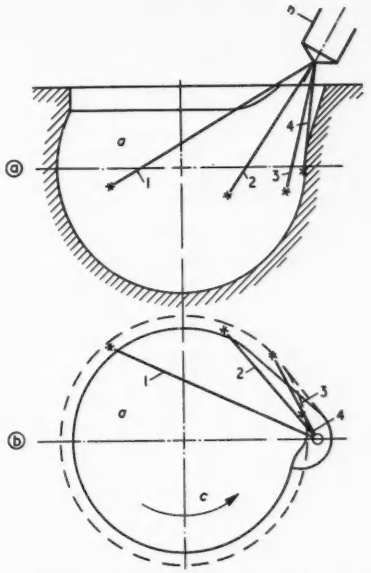


Fig. 1. Details of combustion chamber, shown (a) in elevation, and (b) in plan view, indicating the four jet positions used in soot-deposition tests.
(*a*) Combustion chamber; (*b*) injector; (*c*) direction of air-swirl.

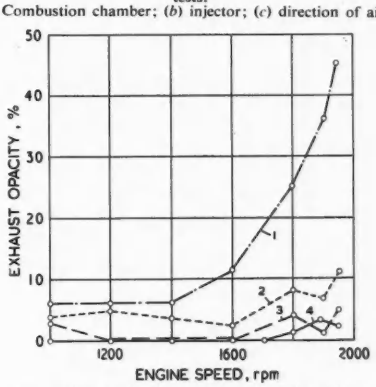


Fig. 2. Comparative results of exhaust-opacity tests with jet positions as indicated in Fig. 1.
0% = complete transparency; 100% = complete opacity.

* Although, of course, pilot-injection systems are quite common, the M-process (after Meurer, the author of this article) is claimed to obviate the disadvantages of previous systems, particularly with regard to excessive fuel consumption, and also to eliminate completely soot in the exhaust.—Ed., E. D.

specific power output, as has been confirmed by tests on an M.A.N. self-aspirating engine of 112 × 140 mm bore and stroke. The M-combustion system also gives excellent results on pressure-charged engines.

Soot Deposition

The M-process endeavours to avoid dissociation of the fuel into hydrogen and carbon before combustion, and analyses have shown very little oxidation of the lubricating oils used and also a particularly low content of free carbon.

This result is undoubtedly due to the formation of the mixture on the combustion-chamber wall and its effect on the combustion process. In comparative tests with otherwise identical conditions as regards air-swirl, combustion-chamber dimensions, and injection quantity, the direction of a single jet was varied from positions (1) to (4), as indicated in Figs. 1a and 1b. It was found that the amount of soot deposition (Fig. 2) was by far the lowest with the jet in position (4), over a running range of from 1000 to 1950 rpm. The exhaust was more opaque with the jet in position (3), much more opaque in position (2), while in position (1) the opacity of the exhaust increased markedly over the same speed range.

Influence of Air-Swirl

Air-swirl in the M-process is not a means of dispersing the fuel but serves to remove the evaporating trails of fuel vapour from the liquid film on the wall as rapidly as possible. In M.A.N. lorry engines, air-swirl is produced by masking the inlet valve during the suction stroke. As this masking reduces the valve cross-section and hence causes pressure losses, other swirl-generating arrangements were successfully developed for the M-system. For instance, a spiral shape of the inlet passage is suitable. Fig. 3 shows the advantages of this arrangement over a masked valve, curve (a) being obtained with the masked valve, and curve (b) with the spiral passage. There are two vertical scales in this figure, i.e., one with the peripheral velocity v_A [m/sec] of the anemometer used, and the other with n_A/n_E, i.e., the ratio of swirl speed to engine speed. The base scale indicates the negative pressure [mm Hg] required in order to generate in a static flow test an axial flow velocity of 10 m/sec in the engine cylinder, the corresponding resulting air-swirl being measured with the anemometer in the combustion chamber. It can be seen from Fig. 3 that, for the same amount of air-swirl, there is less pressure loss with the spiral inlet passage than with the masked valve.

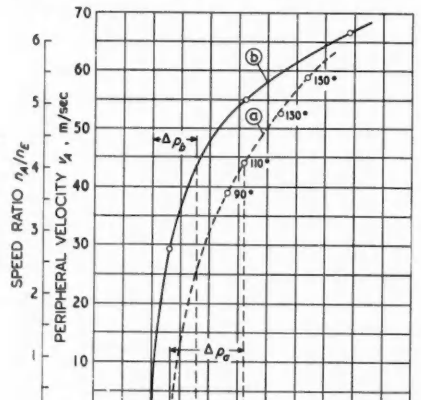


Fig. 3. **Results of comparative air-swirl tests, showing the advantages of a spiral-shaped inlet passage over a masked inlet valve.**
Curve (a): Masked inlet valve, with masking indicated in degrees.
Curve (b): Spiral-shaped inlet passage.
Δp_a, Δp_b: Additional pressure losses corresponding to curves (a) and (b) respectively, to obtain a speed ratio of 4 : 1 for air-swirl.

Cold Starting and Types of Fuel

To a considerable extent, the M-process is not affected by the ignition point of the fuel used; however, this advantage has a practical value only if it is possible to start cold engines on a fuel with a high octane number. As fuel will not evaporate on a cold combustion-chamber wall, the initial ignition must come from the fuel distributed in the air space; for cold starting, this quantity is considerably increased. In addition, there is a very effective rise in the intake air temperature, and this is obtained by means of a small compressed-air burner in the air intake, also using the same type of fuel. With a compression ratio of 19 : 1 and a speed of about 110 rpm, after preheating for 30 sec in ambient air at —20°C, the engine can be brought to its self-operating condition in 20·5 sec on petrol (80 to 86 octane) and then in 9 sec on diesel oil. As numerous other types of hydrocarbons have ignition properties somewhere between those of petrol and diesel oil, the use of such fuels therefore presents no difficulties.

Comparative Indicator Diagrams

Fig. 4 shows two superimposed indicator diagrams obtained from the same engine, which for comparative purposes was operated first with a conventional air-distribution system (curve (b)), and then with the M-system of fuel spraying on the combustion-chamber wall (curve (c)). The TDC line is denoted by (a). For the air-distribution system, the nozzle was turned so that its two jets were directed into the middle of the combustion chamber. In view of the 1 : 4 ratio of nozzle-hole diameter to hole length, the jets remained fairly compact, and some of the fuel may have bounced off the other side of the spherical cavity, after traversing the combustion chamber. However, the length of the path of the free jets was sufficient to give the characteristic peak of normal diesel combustion. Up to the beginning of injection, the curve of the M-process is the same as the conventional diesel curve but, instead of a violent pressure rise and a peak close to TDC, the M-process gives a slow initial rise and a maximum at about 15 deg. crank angle after TDC. Both tests were made with the same injection timing, nozzle, running speed, and mean effective pressure. With the air-distribution system, the

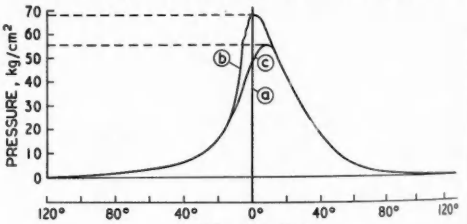


Fig. 4. **Comparative indicator diagrams for the same engine, using a conventional air-distribution system (curve (b), and the M-system (curve (c)).**

highest reaction velocity is at the beginning, whereas with the M-system (wall distribution), it occurs only at the end of combustion. The TDC line divides the intermediate area between curves (b) and (c) into two nearly equal parts, indicating that the pressure rise due to rapid combustion before TDC is compensated by a corresponding pressure variation after TDC. It has no influence on the area of the effective torque curve derived from these diagrams, but serves only to raise the peak pressure.

The M-process thus combines smooth, knock-free combustion with low specific fuel consumption; furthermore, because it is not appreciably affected by the ignition properties of fuels, it enables the compression-ignition engine to be operated on a much wider range of fuels.

CZECHOSLOVAKIA

Improving the Stability of Solid-Type Cable Insulation by Screening

By M. MARSAL. (From *Elektrotechnicky Obzor*, Vol. 44, No. 9, September 1955, pp. 459–469, 20 illustrations.)

As a result of electrical, thermal, mechanical, and chemical processes, the insulation of power cables is subjected in operation to ageing, and the stability of the insulation can be defined as its ability to withstand the influence of these processes. Electrical ageing is caused by discharges in cavities in the insulation, and these discharges can be especially harmful in cables undergoing cooling, when the volume of oil contraction is larger than the volume flowing back from the sheath.*

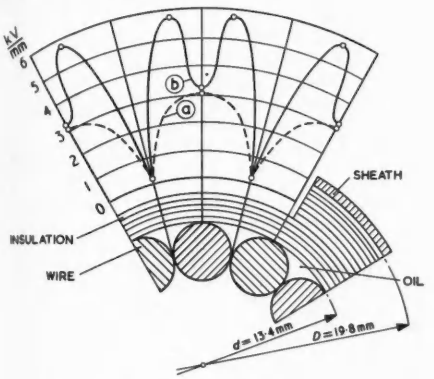


Fig. 1. **Fields produced by an unscreened conductor in a 10-kV cable for (curve (a)) the hypothetical case of a homogeneous insulation, and (curve (b)) an actual case, using oil with a dielectric constant of 2·5 between the wires and impregnated paper with a dielectric constant of 3·8.**

High-voltage cables are usually provided with a layer of metallized paper over the insulation. In such cables the minimum voltage for inception of discharge occurs in the largest cavities near the conductors. It is well known that the electrical stress in the vicinity of stranded conductors is between 20 and 30% higher than in the case of a smooth cylindrical conductor. To prevent the increase in the electrical field caused by the use of stranded conductors, pressure cables incorporate some form of screening, usually by means of metal foil. This, however, is not as yet the practice with solid-type cables, and it was therefore considered desirable to conduct an investigation into the electrical properties of solid-type cables with screened conductors, not only because of reduction in the field, but also because of the possibility of eliminating discharges in cavities near the conductors.

Fig. 1 shows the fields produced by an unscreened conductor in a 10-kV cable for the hypothetical case of a homogeneous insulation (curve (a)), and for an actual case, using oil with a dielectric constant of 2·5 between the wires and impregnated paper with a dielectric constant of 3·8 (curve (b)). Screening with metal foil is not conducive to a radially symmetrical field, owing to pronounced field increases at edges and perforations, as shown in Fig. 2. This effect is, however, less pronounced when screening is effected by means of paper suitably treated with carbon, and the experiments were accordingly carried out with this type of paper only. Carbon-treated paper containing from 10 to 20% carbon has the most suitable conductivity for screening purposes. Conductivity depends also on the mode of absorption of the carbon in the paper, and it is important that the carbon particles should be sufficiently strongly held together. Furthermore, when suitably chosen, the particles have the properties of activated carbon, so that the carbon-treated paper will then act as a filter, absorbing oil impurities after impregnation and the products of chemical ageing processes.

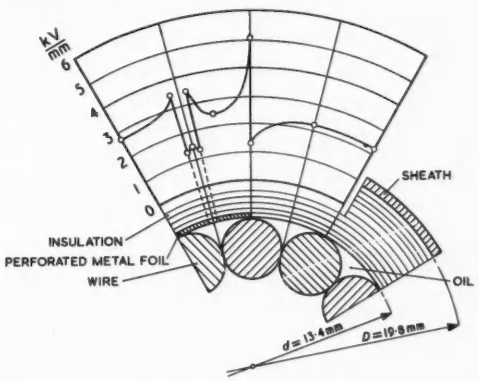


Fig. 2. **Field produced by a conductor in a 10-kV cable, screened by metal foil with a 0·012-in. diameter perforation, using oil with a dielectric constant of 2·5 between the wires and impregnated paper with a dielectric constant of 3·8.**

It was considered necessary to clarify two questions experimentally, i.e., the influence of this screening on chemical processes, and the influence on electrical processes, i.e., discharges. Accordingly, two types of experiments were carried out. In the first type, a number of lead-sheathed samples of cable, using copper or aluminium conductors, 0·08 sq in. in section, with insulation 0·1 in. in thickness, was constructed. Some of these samples

* N. KLEIN: "The Temperature Limit of Power Cables"; *The Engineers' Digest*, Vol. 12, December 1951, pp. 399–402.

had two layers of carbon-treated paper tapes wound around the conductor. The insulation, including the carbon-treated paper, was in all cases built up of twenty layers, and this was surrounded by an additional layer of metallized paper. Three types of impregnants were used, i.e., type OP, consisting of a mixture of mineral oil and polyisobutylene ; type ODK, a mixture of mineral oil and distilled resin ; and type OK, a mixture of mineral oil and resin of the kind usual in cables up to 35 kV. The samples were then maintained at 100°C, the cables being connected to a high-voltage source and the highest stress gradually increased from 3·3 to 8 kV/mm. Ageing processes were observed on six samples by measuring the loss angle δ.

Prior tests on these cables at room temperature (25°C) showed very little difference in the curves of voltage plotted against tan δ in the case of the screened and unscreened samples impregnated with the OP and OK impregnants. Differences were, however, noted between the screened and unscreened samples using the ODK impregnant, the unscreened cable showing an increase in tan δ above 6 kV. The assumption is that this was due to imperfect impregnation and consequent discharge in cavities at the conductor of the unscreened cable. Such discharges could not occur in the case of the screened cable.

At 100°C, considerable differences were experienced in tan δ values, the loss angle of the unscreened cables being much higher than in the case of the screened cables. This is believed to be due to the absorptive properties of the carbon-treated paper.

More pronounced differences were noted when the samples were maintained under identical thermal and electrical conditions and variations in tan δ with time were plotted. The unscreened cables showed marked deterioration, whereas the screened cables remained virtually unchanged. It is also interesting to note that the increase in tan δ of the cables with the ODK impregnant was much more pronounced than that of the cables containing the OP impregnant.

In addition, the loss angle of individual paper tapes was measured before and after the experiments. It was found that the tan δ value of tapes near the conductor was practically the same as that of the other tapes in the insulation of the screened cables. On the other hand, in the case of the unscreened cables, the tan δ value of tapes near the conductor, as a result of the ageing process, became larger than that of the other tapes in the insulation, demonstrating the influence of the carbon-treated papers on ageing.

Finally, the breakdown strength of the samples was ascertained by rapidly increasing the voltage (2kV/sec). The breakdown voltage was found to be about 68·8 kV for the unscreened cables, and about 75 kV for the screened cables.

In the second type of experiments, the object was to ascertain the possible decrease in electrical ageing by the use of screening. As already mentioned, electrical discharges can be especially damaging during cooling conditions, and for this reason experiments involving cyclic loading were carried out, simulating conditions occurring in actual practice, but accelerating ageing by using maximum conductor temperatures of 85 to 90°C, and by using double the nominal voltage V_n of 12·7 kV for the first 50 cycles, then increasing the voltage to $2{\cdot}5V_n$, and subsequently increasing it until breakdown. The duration of the test cycle was 12 hr, allowing 6 hr for heating and 6 hr for cooling. Heating of the samples was effected with a transformer, the secondary of which was the cable itself, the conductor being short-circuited.

In these tests, 22-kV, 0·08 sq in., single-core lead-sheathed cables were used. The insulation of the unscreened cables consisted of 53 layers of paper, and of the screened cables 51 layers of paper and two layers of carbon-treated paper. The insulation was covered with a layer of metallized paper, and the OK type of impregnant was used in all cases. Samples of unscreened and screened cables were then heated with a current of 250 A to between 85 and 92°C, depending on room temperature.

The results of these ageing tests, in terms of the dependence of voltage on tan δ and its increase with the number of load cycles at about 20°C, showed a considerable increase in tan δ after a few cycles at a voltage of $2V_n$ in the case of the unscreened cables, one of which broke down after 22 cycles and the other after 16 cycles at this voltage. With the screened cables, however, the tan δ value increased much more slowly with the number of cycles at $2V_n$, and was much lower before breakdown than it was with the unscreened cables. One screened cable broke down after 49 cycles and the other after 55 cycles at a voltage of $2{\cdot}5V_n$. Once again, the higher tan δ values with the unscreened cables are ascribed to the absorptive properties of the carbon-treated paper in the screened cables. As in the first series of experiments, the loss angle of individual paper tapes before and after testing was also determined, and the results confirmed those previously obtained.

Finally, breakdown-voltage tests as a function of time were carried out on the remaining sections of cables which had not broken down in previous tests. Bearing in mind that the screened cables had an effective insulation thickness which was about 4% less than that of the unscreened cables, the results indicated that the breakdown strength of the screened cables was about 18% higher than that of the unscreened cables.

Inspection of the insulation of the cables after breakdown showed considerable charring of the tapes adjacent to the conductors of the unscreened cables, extending over their entire length. On the other hand, no such charring was observed in the case of the screened cables, and it must be assumed that the charring of unscreened cables is attributable to the increased field. It should also be noted that partial breakdown channels, to a depth of from 3 to 5 paper layers, were found at numerous points in the unscreened cables, whereas no such channels were noted in the screened cables.

As a result of these investigations, it is concluded that the screening of solid-type cables permits a possible decrease in their insulation thickness, as compared with unscreened cables, with the same degree of operational safety ; alternatively, by keeping the insulation thickness unchanged, the operational safety factor can be increased. Furthermore, for the same degree of operational safety, the absorptive properties of the carbon-treated paper permit an increase in operating temperatures. These two possibilities have their own inherent advantages, though at first sight it would appear that a possible decrease in insulation thickness would be the more attractive, owing to the resulting saving in materials. Nevertheless, the possibility of increasing the operational safety factor, thereby increasing the current-carrying capacity of the line, may well be the more important consideration, and only practical experience over a number of years will be able to decide the question as to which is the better alternative.

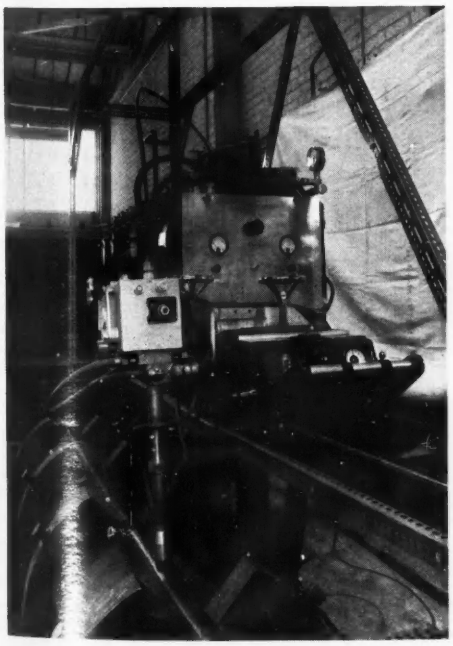
British Industrial Developments

Automatic Argonaut Welding

The addition of automatic Argonaut welding to their existing range of Argonaut equipment is announced by The British Oxygen Co. Ltd., of London, W.1. Normally, a hand gun is used in the Argonaut inert-gas-shielded electric welding process, which is particularly suitable for the rapid welding of heavy sections of aluminium, stainless steel, copper, and mild steel. Now, however, a new automatic Argonaut head provides fully automatic mechanized equipment for the production welding of heavy sections of metals, the advantages of this equipment being its high welding speed, smooth weld bead, even and controlled penetration, and freedom from porosity.

The new equipment, which is particularly suitable for the welding of mild steel, is designed to handle 600 A d.c. continuously and can be used with 0·035, 0·045, $\frac{1}{16}$, $\frac{5}{64}$, and $\frac{3}{32}$ in. diameter " hard wires ", i.e., stainless steel, copper, bronze, and steel, and also with $\frac{3}{64}$, $\frac{1}{16}$, $\frac{3}{32}$, and $\frac{1}{8}$ in. diameter aluminium-alloy and magnesium-alloy wires. The unit consists of a welding head which houses the wire-feed mechanism, a water-cooled machine barrel, a reel-casing assembly with mounting bracket, a wire casing to feed the wire from the reel-casing assembly to the welding head, a main control panel, and a remote control panel. Other devices, such as a motorized carriage unit or motorized work positioners, will also be needed, depending on the individual job, i.e., these mechanical devices will move either the head or the work, so that the weld follows the seam.

Whereas the manual Argonaut gun uses a variable-speed constant wire-feed motor, and arc voltage is maintained constant by the principle of self adjustment through automatic changes of wire " burn-off" with changes of arc length, the automatic head maintains constant arc voltage by varying wire-feed speed. Constant welding conditions will thus be precisely maintained through the automatic speed regulation of the welding wire into the welding arc. A simple electrically controlled motor drive actuates the feed rolls. Two wire-speed ranges are provided, i.e., 80 to 350, and 150 to 450 inches per minute, respectively. For extra-high speeds, special gears can be supplied to increase the wire speed to 750 ipm. The main control cabinet contains the less frequently adjusted controls, i.e., a polarity switch, a high-low wire-speed switch, and basic arc-length control. Meters are built into the front panel to indicate arc voltage and welding current. These meters simplify and accelerate setting up and checking for optimum welding conditions. The more frequently used controls required by the operator are all contained in a small remote control box. This small unit is designed for convenient mounting at the operating station. The control system also provides a circuit which may be used for starting and stopping the welding operation by switching the field current of the welding power source. A water-pressure switch is incorporated in the controls, so that welding cannot be started unless there is positive water pressure in the cooling system. Slow wire down-feed control permits smooth arc starting. Stub burn-off control eliminates welding wire freezing into the weld pool at the end of operation.



A 600-A composite dry rectifier has been designed for use with the Argonaut automatic head. It comprises a 3-phase transformer, with primary tappings for 360, 330, 400, 420, and 440 V, 3-phase 50-cps supply, and a dry-plate selenium-type rectifier, fan-cooled, with automatic protection against fan-motor failure. Remote control of the whole range of welding currents from 50 to 600 A is effected by means of a rheostat controlling the current to a magnetic amplifier. A single-pole 600-A d.c. welding contactor is incorporated in the set and is controlled through the welding head.

In the accompanying illustration, the automatic Argonaut unit is shown mounted on its track, and the smooth weld bead possible with this equipment can be seen underneath the torch head.

Portable, Trolley-Mounted Fire-Fighting Unit

The development of an entirely new type of self-contained, portable foam fire-fighting appliance has been announced by The Pyrene Company, Limited, of London, S.W.1. The new unit, Model A.F.30C, is trolley-mounted and has a capacity of 30 gal, producing more than 400 gal of mechanical foam for use against outbreaks involving quantities of oils, spirits, fats, and other inflammable materials. It has been designed to meet a wide variety of fire risks, and has many distinct advantages over the more widely used chemical-foam engine. It is particularly suitable for use where water mains do not provide sufficient pressure for other forms of mechanical foam-making equipment. Additional advantages are that it can easily be manoeuvred and operated by only one man and that recharging can be completed on the spot within a few minutes. Furthermore, it maintains its efficiency over a wide range of temperature.

The 30-gal cylindrical tank comprising the main body of the unit contains a pre-mixed solution of water and " Pyrene " foam compound. Discharge pressure is provided by a cylinder of CO_2 gas, which is connected to the main container by a short length of flexible high-pressure hose, the CO_2 cylinder being fitted with a sealing disc and a lever-operated piercing head. A syphon tube fitted in the tank is coupled to a 30-ft length of hose, which is car-

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ried on a hose saddle clamped to the main container. Foam is generated at the delivery end of the hose by a specially designed miniature "Pyrene" foam-making branch-pipe. The unit is operated simply by unwinding the hose and pulling the CO_2 lever in an upward direction. Total discharge is completed in two minutes. The two-wheeled trolley is of light, tubular steel construction and is designed to operate in the upright position. The unit weighs 670 lb when charged, and is 4 ft 11 in. in height and 2 ft 7 in. in width.

Resurfacing Coal-Pulverizing Mill Rolls, using Automatic Welding

Power stations in Great Britain use pulverized coal as their raw material, and an important problem is the satisfactory maintenance of roll surfaces in the pulverizing mills, so much so that considerable experimental work has been done in co-operation with various manufacturers.

The most economical solution to give entire satisfaction has been the Metrovick automatic welding plant installed experimentally by the Metropolitan-Vickers Electrical Company Limited, of Trafford Park, Manchester, at the South Eastern Divisional Workshops, Croydon "B" Power Station. This has been in operation since September 1954, and at the present time is being prepared for trials with submerged arc welding ; judging from experiments carried out, this should give even better results than those achieved so far.

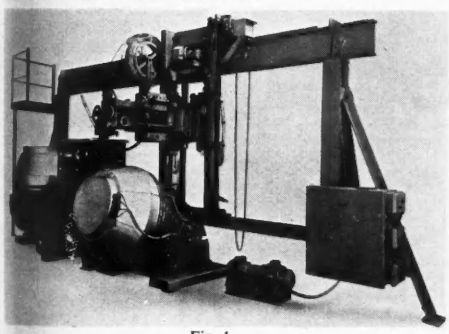


Fig. 1

The complete machine is shown in Fig. 1. One jig is tilted in the weld position, and the other is horizontal in the loading position. The main control panel stands centrally between them, and the electronic control panel is mounted on the right-hand side frame. The small motor-generator set supplies low-voltage direct current for the arc control circuit. The automatic welding head, suitable for continuously coiled fluxed electrode, is mounted on a projecting roller slide, which moves the head outwards and inwards over the face of the mill roll. The roller slide, which is motor-operated, works in unison with the welding jig and is held in a vertical slide frame, on a travel carriage, capable of a 29-in. vertical adjustment. This carriage can be moved along a 21-ft railed track by a chain pulley drive and locked in any position along the track, thus allowing the welding head to be placed over either of the two welding jigs.

The welding jigs comprise a tilting table holding the mill roll, which is rotated at welding speed by a variable motor drive. The table can be tilted to any angle between the horizontal and 30 deg. past the vertical (i.e., a 120-deg. movement), thus facilitating loading and welding. The jig-rotating motor and the head projecting slide motor are electronically controlled and locked together so that, as the work rotates, a continuous spiral weld deposit is made on the mill-roll face. The various sizes of rolls have a switch index on the control panel which presets the

Fig. 2

controller speed for the different diameters of the rolls and also automatically adjusts for the degree of taper on the roll face. On this machine two tapers are catered for, and the amount of overlap of the spiralling weld can also be varied by adjusting the appropriate potentiometer inside the control panel.

The head projecting slide drive can be disengaged and the slide manually adjusted by a handwheel at the front of the machine ; alternatively, a split-nut release feature allows for quick positioning manually. A stationary head is necessary on the build-up at the ends of the roll and for filling in cavities in the worn roll face, and the drive clutch is thrown into the disengaged position for these runs.

Fig. 2 shows the inside of one oven dismantled from the table and a mill roll mounted on the table. Oven temperature is automatically controlled during preheat, welding, and post-heat periods. The temperature programme controller is arranged to switch on the heaters automatically for preheating and to switch them off at the end of the post-heat period. Temperature limit control is effected by thermocouples mounted on spring-loaded arms bearing on the inside machined surface of the mill roll. The oven is heated by three banks of standard Metrovick tubular sheathed elements totalling 16 kW.

The main control panel has the automatic temperature control instruments at the top and the presetting switches at the bottom, with the operating push-buttons for the various functions located in between.

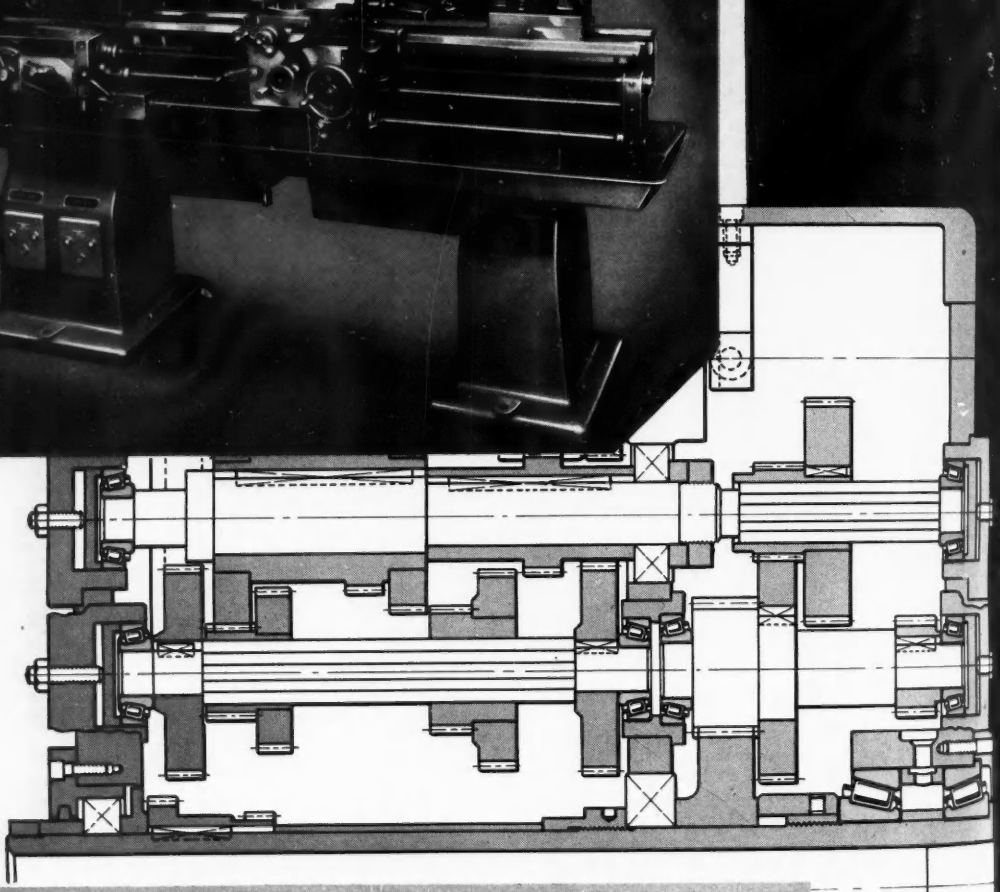
New Automotive Transmission Factory

The new factory of Borg-Warner Limited at Letchworth has been specially designed to produce at a high rate fully automatic gear transmissions and automatic overdrives, two of the main products of the Company. On a total site area of some 11 acres, the building provides 198,000 sq ft of single-floor productive space, while essential services covering the needs of the highly complex and special equipment used have been located under the balconies running the full length of the east and west sides of the factory. Here, four automatic oil-fired boilers of the latest package type have been housed and are capable of producing a total of 28,000 lb of process steam per hour.

The air-compressor installation of six double-acting compressors with after-coolers, producing 4400 cu ft per hour, supply the numerous air fixtures, gauges, and pneumatic operations throughout the factory. Electric power, taken from the 11,000-V ring main, has been split to four sub-stations, which combine to feed a total demand of 5500 kVA.

The pattern of production through the factory has been designed to carry the components from the raw-

On a 13-in. swing centre-lathe



The line drawing shows a characteristic use of Timken tapered-roller bearings on the work spindle. The spindle of this Henry Milnes lathe is supported at the nose end by a pair of Timken bearings; the parallel-roller and ball bearings constituting the other supports are arranged to permit axial freedom for expansion and contraction. In this way the spindle is end-located close up to the work by the pair of Timken bearings and without possibility of disturbance of the pre-loading.

It will be noticed that the use of the Timken flanged bearing enables the housing to be bored for both bearings at the same setting, thus maintaining concentricity. The flange of the right hand bearing is clamped against the housing by the cover, and thus locates both bearings and thereby the spindle, and incidentally provides a register for the cover.

As will be seen, Timken bearings are also used on the driving shafts.

This and many other examples are illustrated in our machine tool manual, available on request.

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material stage, following the route of machining, hardening processes, grinding, and finishing, through to assembly, testing, and despatch. Adjacent to the receiving docks at the south-east corner, a marshalling area has been allocated for the palletization of raw-material stock, the various forgings and castings being fed to the machine lines by means of skid-boxes.

The cast-iron line has been equipped with the latest type of machines of highly specialized automatic and continuous transfer type, typical of which are the two-way horizontal transfer machines which handle the main-case casting. Castings are automatically cycled on a continuous feed through the 16 operating heads, which perform in total 50 individual operations. Steel-turning and gear-cutting machinery has been laid down to produce the fine precision parts essential in these transmissions. Of particular interest in the steel lines is the battery of 8-station automatic hobbing machines and the high-speed fully automatic internal gear-shaving equipment, capable of producing finished gears at a rate of 30 per hour.

The heat-treatment department has been located within the production area and forms part of the continuous flow of production. Two of the latest electronically controlled pit-type furnaces have been put down and the large rotary furnace is arranged with continuous quenching. The hard-grinding department has been equipped with automatic sizing-type grinders, while cam grinding is carried out on hydraulic cam contour grinding machines.

All components have been palletized to move to the manufactured-parts storage area, from which they are fed through steam pressure washers by means of closed-circuit continuous overhead conveyors. The conveyors carry manufactured and purchased parts into the assembly department, which has been designed to give air-pressurized, dust-free conditions. Assembly has been planned on the continuous-conveyor method, from the individual component to sub-assemblies, through to the finished transmissions, the completed units moving to final testing over the dynamometers. Here, running tests have been simulated to give overload conditions. The shipping area has been located outside the assembly department, from which palletized transmissions can be loaded directly to road-transport vehicles.

Service departments, including gear laboratory, inspection, metallurgical laboratory, tool room, cutter grind, machine maintenance, etc., have been positioned throughout the factory to give maximum efficiency to production. Technical administrative and clerical offices have been located in the front block and side upper balconies.

New Factory for Automatic Electroplating Machines

The new factory of the Electro-Chemical Engineering Co. Ltd., suppliers of plant and processes for the electroplating and allied industries, was recently opened at Sheerwater, near Woking, Surrey—the new headquarters of the Company. At the new factory the assembly and mechanical testing of Efco-Udylite automatic machines is carried out, as well as the mixing and packaging of the range of chemicals used in the various Efco-Udylite processes. In the laboratories the routine analysis of customers' solutions is undertaken, and new plating processes are tried out and demonstrated.

The site of the new factory covers three acres, initial development being over a frontage of two-thirds of the area. The factory consists of six bays, each 35 ft in width, five of these having a length of 66 ft and a height to the underside of the truss of 16 ft. The sixth bay has a length of 88 ft and a height to the underside of the truss of 23 ft, this bay having a 3-ton overhead crane. Fig. 1 is a view of part of the factory, showing automatic plating machines under construction.

Three bays are in use for chemical products and three for engineering. A building, 20 ft in width, is connected

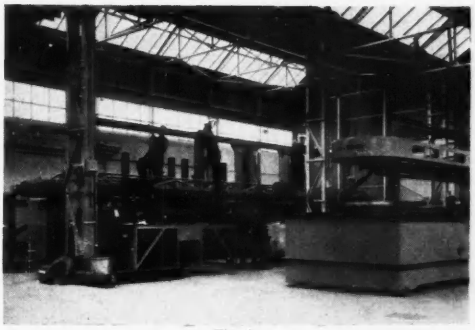


Fig. 1

to the main factory and runs the full width of the six bays (210 ft); this contains the demonstration plating shop (Fig. 2), analytical and development laboratories, and offices for chemists. To the north is a separate office block of two floors, connected to the works by a covered way. The buildings have been laid out in such a manner that they can be readily extended without interruption of the existing processes; in this connection, the factory will eventually be extended by at least 100%. Provision has also been made for the extension of the office block by 70%, and roads and services have been laid out with these future extensions in view.

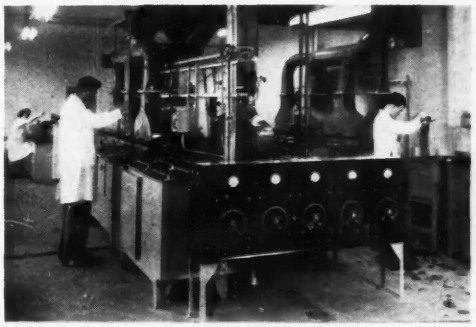


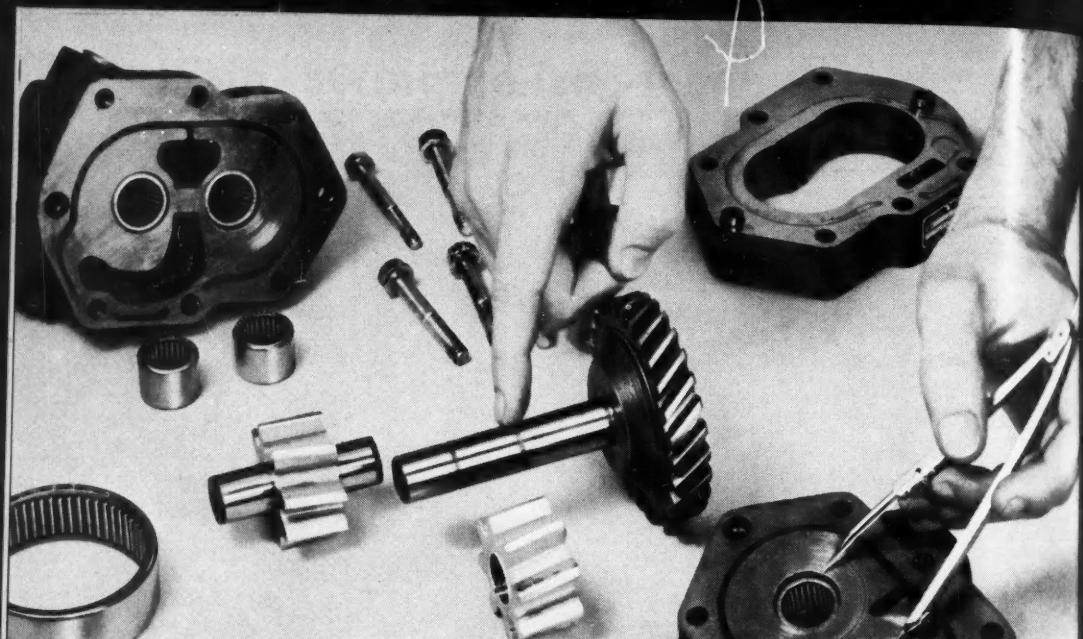
Fig. 2

The products of the Company include fully automatic electroplating, anodizing, and pickling machines, and semi-automatic plating machines. Under an agreement with the Udylite Corporation, of Detroit, the Company supplies Udylite bright-plating processes, comprising bright-nickel, bright-zinc, and bright-cadmium, and also manufactures under licence "Di-phase" cleaning equipment and cleaning processes, together with automatic degreasing equipment.

New Aluminium Alloy for Busbars

Combining strength with lightness and high current-carrying capacity, a new aluminium alloy for busbars, designated Noral D5OS, is announced by the Northern Aluminium Company Ltd., of Banbury, Oxfordshire. Expressly developed to produce a material with the best and most economical combination of mechanical and electrical properties, Noral D5OS has physical properties such that, with the increase in size necessary to compensate for its lowered conductivity, compared with copper, busbars of this alloy are mechanically, as well as electrically, equivalent to their copper counterparts. Its minimum ultimate tensile strength is 13 tsi, minimum 0·1% proof-stress 10·5 tsi, and its electrical resistivity 3·133 microhms/cm at 20°C.

Being a fully heat-treated magnesium-silicide alloy, its conductivity is lower than that of the aluminium of



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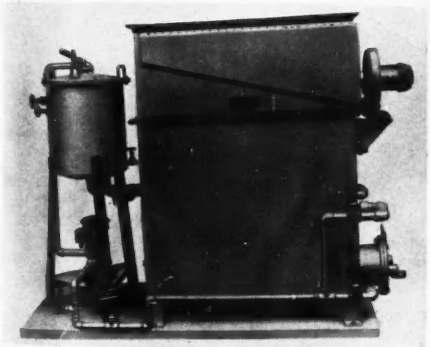
electrical purity hitherto generally used for busbars—the addition of any element to pure aluminium is bound to have this effect. Against this, however, must be counted the fact that its temperature coefficient of resistance is lower than that of aluminium of electrical purity. This feature does to some extent offset its slightly lower conductivity ; busbar ratings are specified in relation tc the temperature rise expected above a stated ambient temperature, and for a 40°C rise on a 30°C ambient, Noral D5OS alloy bars may be rated at 96% of the values given to geometrically similar bars of electrical-purity aluminium. The new alloy is available in the form of extruded sections and could be made available in the form of plate when very large rectangular bars are required.

New Metal Drying and Cleaning Processes

Developed in Germany by Wacker-Chemie, the "ASL" method of drying metal parts rapidly and without traces of water staining, and the "Pertrinol" metal cleaning process have been introduced by Roto-Finish Limited, of London, W.1, who have been appointed sole licensees in the United Kingdom.

The "ASL" drying method consists of immersing the parts to be dried in boiling perchlorethylene to which has been added a special agent. This agent has the property of reducing the adherence of water to the surface of metal and of promoting the transference of heat from perchlorethylene to water. The result is that the water evaporates much more rapidly than in pure perchlorethylene and does not tend to form an emulsion. Owing to the speed of evaporation, all the impurities in the water are removed simultaneously from the surfaces of the metal parts, leaving them stain-free. The "ASL" additive is so efficient that only minute quantities are required, a ratio of 0·1% by weight of "ASL" to perchlorethylene being satisfactory. In addition to the "ASL" agent, "ASL" metal-drying plant is also being marketed. This plant incorporates a water separator which ensures that the drying process is maintained without risk of deterioration from water contamination of the bath.



In the "Pertrinol" metal-cleaning process, the equipment used is similar in principle to that of a liquor/vapour-solvent degreaser but incorporates three separate compartments. The main cleaning action is achieved in the first compartment, which usually contains boiling trichlorethylene. In the past it has been found that trichlorethylene rapidly dissolves oils, fats, and grease, but it often fails to remove the fine insoluble particles from polishing and buffing compositions. In the new process, this soil is removed by adding fine plastic particles (which can be either globular or fibrous) to the trichlorethylene. This plastic material, called "Pertrinol", does not disintegrate in the hot solvent but becomes slightly swollen and softened. When a 5% addition by weight of Pertrinol is added to boiling trichlorethylene the Pertrinol particles circulate automatically and, as soon as the wax or grease has been dissolved by the solvent, scrub the surface of the component, rapidly removing all traces of dirt. The Pertrinol particles are so fine that they penetrate into crevices, threads, etc., achieving a degree of cleanliness which previously has been possible only by additional hand-scrubbing. After immersion in the first compartment, the metal parts, contained either in a barrel or a perforated basket, are transferred to a second compartment containing cold solvent. This serves to wash off any remnants or Pertrinol particles which may have been carried over and to cool the metal parts so that they can be given a final vapour degreasing in the third compartment. In order to maintain a high degree of cleanliness, provision is made in the Pertrinol plant for continuous circulation and the return of clean solvent to the cleaning apparatus. The illustration shows a Pertrinol metal degreasing and cleaning plant with an electrical heating system, exhaust system, and large Pertrinol trap.

It is claimed that, with the new process, a much higher standard of cleaning is possible than with standard solvent degreasing equipment, involving only the negligible cost of replenishing some of the Pertrinol particles each month.

New Finishing Process for Aluminium

Providing a product which is stated to be comparable in finish, far more durable, and in many cases cheaper than the majority of chromium-plated articles, the "Eftwerk" process is a simple and economical method of chemically brightening aluminium. Originally developed in Germany and extensively patented, it is now available in Great Britain on a commercial basis, as the result of an agreement with The London Aluminium Company Limited, of Witton, Birmingham, who have been appointed the first licensed operators in the U.K.

With this process, components are immersed in a solution consisting mainly of ammonium bifluoride and nitric acid. The rate of attack on the metal is very high, and brightening is achieved within 20 to 30 sec. Unlike other processes, careful pre-polishing is not essential and, besides saving labour costs on this operation, the process is invaluable in dealing with components which are difficult or impossible to polish. After brightening, components are given a special anodizing treatment at high voltage and low temperature in a sulphuric acid electrolyte, and the anodic film is then sealed in boiling water. If desired, this film can be given any colour required, by immersion in a dye vat, prior to sealing. The hard transparent oxide film formed gives protection against attack from the worst industrial and marine atmospheres.

Only super-purity base material will give an anodic film of sufficient depth to ensure durability, whilst still remaining transparent, thus retaining brilliancy. With lower grades of aluminium, the impurities will blur this film, thus impairing brilliancy. A three-year trial period

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in replacing chrome-plated steel, brass, or zinc by super-purity aluminium in automobile trim, led the German car industry to use this material on an ever-increasing scale. During this period, it is stated that virtually no claims for replacement of super-purity parts were made, and that manufacturers have expressed complete satisfaction with the working characteristics of the material.

Thermoplastic Wire-Covering Equipment

It has been announced by Metal Industries Limited, of London, S.W.1, that the " Davis-Standard " range of extrusion equipment for rubber and plastics, which is very well known in the U.S.A., is now to be manufactured under licence in Great Britain by Fawcett-Finney Limited at the Bromborough works of Fawcett Preston & Company Limited.

The principal units in the " Davis-Standard " thermoplastic wire-covering line are the pay-off, the extruder, the cooling system, the capstan, the measuring unit, and the take-up. The function of these units can be briefly described as follows :—The bare wire travels from the pay-off reels through the extruding-machine head, where it receives the coating of insulating material, and thence through the water-cooling troughs, where the coating is set. Thereafter, it is drawn around the wire-pulling capstan, and from there to the take-up reels. All units in the line operate at speeds synchronized with the speed of the extruder.

The " Davis-Standard " pay-off machine handles uncovered wire reels up to 36 in. in diameter. Features of the pay-off are self-braking actuated by wire tension, ball bearings for easy starting and running, and pneumatic reel lifting and lowering to and from floor level.

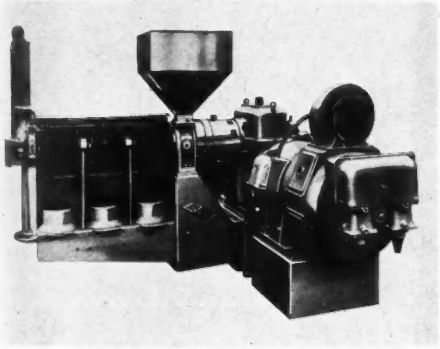


Fig. 1

The extruder (Fig. 1) is designed for high-speed production. The compound feed hopper has a built-in shut-off slide and a compound level-indicating window. The feed throat is provided with a large jacket for temperature control and can be arranged for either powder or strip feeding. Sectional-type cast-steel cylinders offer special advantages in precision temperature control and easier maintenance, while each cylinder section is fitted with wear- and corrosion-resistant removable liners. An outstanding feature of the extruder is the " Therma-Fin " patented heater-cooler units. These are of cast aluminium, machined in pairs to fit the cylinder. Each half has cast-in tubular heating elements. This feature eliminates overheating and ensures long life. Blower units are incorporated, one for each heater, these serving to remove excess temperature and enable the heaters to control temperature very accurately. The head design on the extruder is particularly noteworthy. Both straight and crossheads are hinged for easy cleaning and adjustment. The opening or closing of the head is accomplished by the release of one nut on the clamping mechanism, which

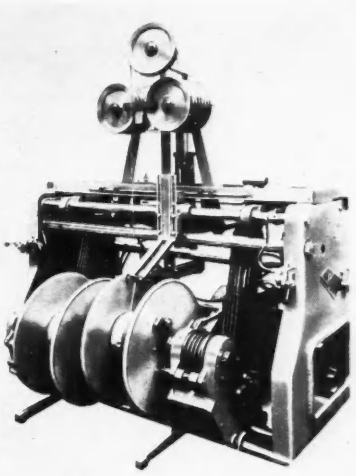


Fig. 2

also incorporates a shear-pin to operate at any desired overload. Die-holders are of the floating type, permitting very easy centering. All heads are designed for the duty required, and those for thermoplastic operation may be of stainless steel, if required, with all movable parts hardened and ground.

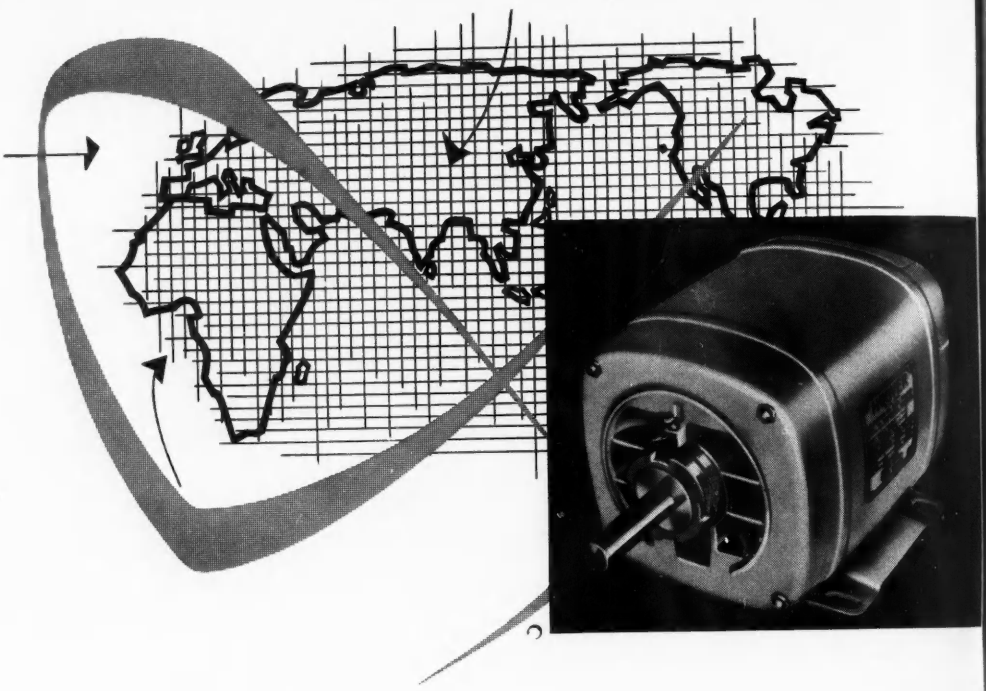
The cooling troughs are of stainless steel with constant-flow water. Trough units in convenient lengths can be continuous or divided into separate cooling zones.

The capstan and its synchronizing control equipment is an ingenious solution to the problems of wire speeds relative to the extruder. The variable-speed motor is electronically coordinated with the extruder motor, in order that the wire speed will be proportioned to the extruder output. The drums rotate in a built-in water sump, access to which is effected by raising a counter-balanced side panel.

The wire-measuring machine handles wires and cables up to 3 in. in diameter and at speeds up to 50,000 yards per hour to an accuracy within 0·1%. It is fitted with a totalizer counter as standard ; alternatively, the counter can incorporate a limiting device which passes an electrical impulse to the take-up on reaching a predetermined level.

The dual take-up (Fig. 2) has no gears or clutches, and is designed to operate smoothly and efficiently at high speeds in continuous service. The transfer of wire from reel to reel with pneumatic raising and lowering is entirely automatic, requiring from the operator only replacement of the full reel with an empty reel. Reel drive is by double V-belts, with a brake which stops the reel as it is disengaged. Traverse mechanism is of a new and improved design, positive in action and with variable speed to ensure a smooth lay. Reels are raised and lowered to and from floor level to eliminate damage. A choice of speed ranges (synchronized with the other units installed as part of a full extrusion line) is provided, while an efficient dancer control column ensures constant tension.

Other machines in the " Davis-Standard " range now being made by Fawcett-Finney Limited include continuous vulcanizers and rubber extruders, in which the wire or core leaves the pay-off for the extruding machine, where it is covered with rubber and delivered directly to the vulcanizing tube through a sealable splice-box integrated with the extruder head at speeds determined by the capstan. Leaving the tube through the seal mechanism, the wire is passed through a cooling trough and thence to the take-up.



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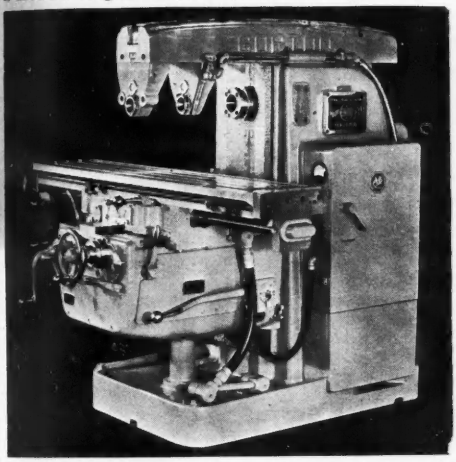
New Materials, Processes, and Equipment

HORIZONTAL MILLING MACHINE WITH DOUBLE OVERLOAD PROTECTION

A new medium-duty horizontal milling machine, with a full-width knee and with double overload protection for cutters, in addition to a standard circuit-breaker in the control panel, has been developed by the George Gorton Company, of Racine, Wisconsin. The spindle of the machine is powered by its own individual motor through a simplified and highly efficient gear train, the power available being 7½, 10, or 5–10 hp (two-speed), depending upon the spindle speeds required. A separate motor (either 2 or 3 hp, according to the feeds desired) is used for longitudinal, cross, and vertical power feeds.



The full-width knee is securely mounted on the column by a square lock bearing of generous width. This knee is 24½ in. wide, i.e., almost as wide as the saddle is long, ensuring maximum rigidity under heavy cutting loads by providing a support to the workpiece closely approaching that of a bed-type machine. A narrow centre guide bearing is provided on both column and knee, to furnish a positive guard against tipping of the knee and cocking of the saddle. The simplified gear train, with only two gear contacts between motor and spindle at any speed, helps to ensure increased usable power at the spindle, less friction and wear in the gear train, and lower maintenance costs.

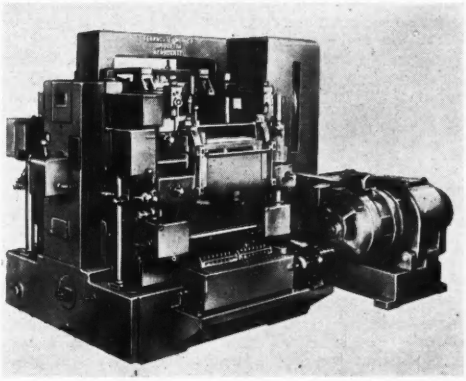
The machine has an extra-long saddle with integral cross-rib construction, bored for bearing- and longitudinal-nut mounting (eliminating bolted bearing-cap construction). This exclusive saddle design includes a totally enclosed coolant channel which in no way reduces the bearing area. Access to the easily adjusted compensating backlash nut is from the front of the saddle. The knee feed-box, the feed-distribution assembly, the speed-box, and the rear controls are all of unit construction, providing obvious adjustment and maintenance advantages. Overload protection is built into the feed-box to stop all feeds when for any reason the cutter becomes overloaded or jams. The coolant pump and motor are concealed in the column base below the main control panel, with easy access through a hinged door. A removable coolant pan is another exclusive feature and saves hours of clean-out time during the year.

An additional horsepower-meter is a safeguard against overloading; furthermore, it acts as a protection against cutter breakage and is a positive indicator in cases where the machine is not being used to its normal capacity.

The machine can be used for plain milling with absolute assurance that no creeping or other movement of the swivel block will take place. In the plain-milling position the swivel block is locked rigidly in place by four ⅝-in. bolts and four ¾-in. bolts. Clamping and bearing spread is 28 in., providing greater stability and rigidity. Unlike the conventional type of swivel block, which turns on a circular bearing surface of limited area, the swivel block of this machine is the full size of the saddle, giving a positive bearing spread of 26 in., even at a 45-deg. angle. The swivel block is rigidly locked in any position by two curved (T-shaped) clamping segments. Four ⅝-in. bolts provide positive clamping action for the two curved segments, which have a centre-to-centre spread of 17 $\frac{7}{16}$ in. The swivel block and saddle also contain a concealed coolant return channel, so that no extra hose or piping is necessary.

SUPER-SPEED PRESS

A new super-speed press, the die-bed of which reciprocates in a horizontal plane, the amount of travel being adjusted to the feed required, has been developed by the Ferracute Machine Company, of Bridgeton, N.J. The punch member takes its motion directly from the crankshaft, the amount of stroke also being adjustable. This rotary motion of the ram at all times follows the reciprocating die-bed. The material is held between the punch and die, both members travelling forward horizontally as the punch penetrates the work, passes the centre point, and withdraws from the work. The material is fed forwards by feed rolls driven directly from the crankshaft, feed-roll speed being controlled through a variable-speed drive, which may be adjusted while the machine is running to synchronize the feed of the material or to produce the least possible amount of scrap. Cam-operated feed-roll lifters release the rolls while the stripper is in contact with the material and while piloting and forming are being carried out.



With this new press there is no lost motion, because the material moves continuously while the work is being performed. This principle makes possible production speeds limited only by the physical characteristics of the product and the maximum speed of the machine. Furthermore, it takes standard die sets, is easily and quickly adjusted, can produce high-quality work in large quantities, and can do the work of several conventional presses. Optimum efficiency is obtained by feeding coil stock;

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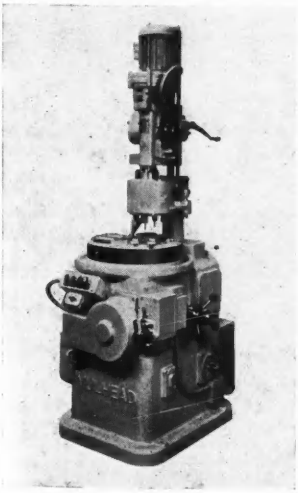
however, strip stock can also be economically processed.

The press is adapted to long or short runs, because the time required to change dies is no longer than it is with conventional presses ; in addition, its action reduces the expense of regrinding by no less than 60 to 80%, while die life is increased in the same ratio, owing to the principle of combining impact with pressure. Accuracy in spacing is constantly maintained, and the application of the continuous-feed principle never allows the stock to stop. The feed rolls can be adjusted to release stock when it is being held by the stripper or punch, although forward motion is maintained by movement of the die-bed. Avoidable waste of stock is reduced to a minimum by adjusting feed while the press is in motion. Stacking chutes can be used to stack the blanks.

SELECTIVE INDEXING HIGH-SPEED DRILLING AND TAPPING MACHINES

Manufactured by the Mulhead Engineering Co. Ltd. and shown at the recent International Machine Tool Exhibition by the sole agents, Thomas Ryder & Son Ltd., of Bolton, " Rota-matic " drilling and tapping machines represent a marked advance on conventional machine design. These machines provide in one unit a built-in rotary table, 18 in. in diameter, which indexes in sequence with either a vertically mounted, hydraulically operated multi-drilling column or a controlled-pitch multi-tapping column (as shown in the illustration). The rotary table is electrically driven and, by dial selection, gives 30, 60, 90, or 120 deg. indexing, as required. The handling of a wide variety of different-size components and a diversity of operations are thus possible.

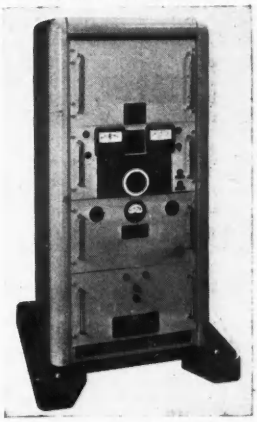
The provision of interchangeable multi-spindle heads (mounted to the drilling or the tapping columns) and interchangeable table plates (which can be pre-tooled and substituted complete) allow the machine to be switched quickly from one machining cycle to another without losing the maximum rates of output normally obtainable only from single-purpose machines. The design of the multi-spindle heads to suit specific operation, in conjunction with the multi-station rotary fixture, permits numerous operations to occur simultaneously to one or more components at adjacent stations on the rotary table. By this means all holes in a part may be drilled or tapped simultaneously, even though the varying centre distances between adjacent holes would normally make this impossible. Alternatively, progressive operations, such as drilling or reaming and countersinking or counterboring, may be performed simultaneously without form-cutters.



" Rota-matic " rotary indexing eliminates operator idle time by arranging for loading and unloading of parts at the front stations of the rotary table during the cutting cycle.

BREMSSTRAHLUNG THICKNESS GAUGE

By making use of a beta-emitting radioactive source and applying it in a novel manner, a nucleonic thickness gauge, utilizing the resulting bremsstrahlung to measure successfully in the thickness range between 0·020 and 0·250 in. in steel, has been developed by the Baldwin Instrument Co. Ltd., of Dartford, Kent.



By thus bridging the gap between the satisfactory use of ordinary beta-gauges, with their top limit of about 0·020 in. in steel, and gamma-emitting sources (above 0·250 in.), it is now possible, by means of three types of Baldwin gauges, i.e., beta-, bremsstrahlung-, and gamma-gauges, to measure thicknesses from 0·0005 to several inches in steel—an extremely important consideration in many rolling mills.

ADVANCED PLAN-FILING SYSTEM

Giving instant location and eliminating searching, misfiling, thumbing, curling, creasing, and rubbing, an organized system of permanent record and filing of drawings, tracings, and prints has been perfected by Steeldex Ltd. (Planfinder Division), of Richmond, Surrey.

The new system, designated " Planfinder ", consists basically of a rigid back and a flexible top cover of strong pasted manilla, complete with index. The outer covers are hinged by a two-piece spine, each piece shaped to an acute angle bearing a bevelled edge. When the two-piece spine is in position, the two bevelled edges form a cone along its front edges, preventing the uppermost half of the leading edges of the drawings, which rest on the rising plane of the cone, from nipping the leading edges of the bottom half, which rest beneath the lower plane of the cone. In practice, this assures ease of manipulation for withdrawal and replacement, and eliminates the possibility of mutilation, etc.

Between the spine, separator guides are gripped at equidistant intervals, creating a visible edge bearing the drawing number. Each succeeding separator is on a slightly higher plane than the one preceding, thus allowing a certain amount of air space and ensuring that all drawings lie flat. This gives ease of withdrawal and replacement, and eliminates curling, creasing, and rubbing. Each separator guide has a visible edge which bears the number of the drawing it houses, giving instantaneous, visible location, which, in turn, eliminates corner thumbing, misfiling, searching, and waiting time. The separator guides also incorporate a permanent printed record for issue and return, thus centralizing all recording, and at once giving a history of movement.

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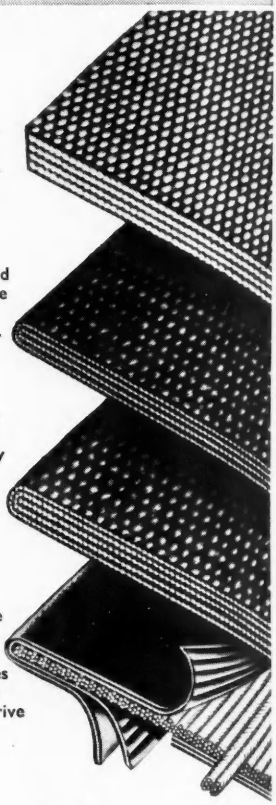

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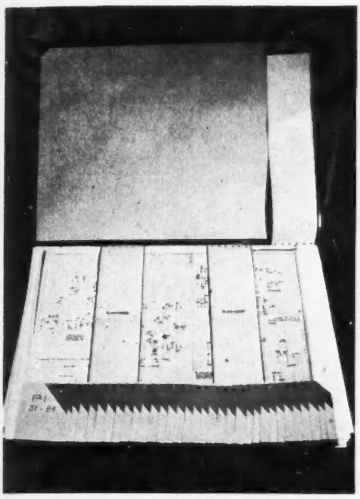
TRANSMISSION BELTS • V-BELTS • HOSE • CONVEYOR BELTING • FENDERS

The Goodyear Tyre and Rubber Company (Great Britain) Limited, Wolverhampton



The " Planfinder " is being produced in eight models, to meet different requirements and sizes, ranging from Half-Imperial (23 × 18 in.) to Double-Elephant (41 × 31½ in.). Furthermore, although they can be housed in existing filing chests, a special chest, known as the " Plan-Houser ", has been developed, offering easier access to the " Planfinders " and providing a valuable saving in floor space. In effect, the " Plan-Houser " is a well-designed metal rack which houses 20 " Planfinders ", representing 1000 drawings, in a space of 25 × 33 × 45 in. high.

LIGHTWEIGHT SOFT-FACED HAMMERS

The latest addition to the range of soft-faced hammers manufactured by the Thor Hammer Company, of Birmingham, is a hammer with a cylindrical non-metallic head fitted with two screw-in faces made from plastics or other materials. The head is particularly strong and will not split, even under heavy blows or under hot and humid conditions. A reverse-taper " eye " is made to take the handle, which itself is of a new type and is self-tightening. This handle can be fitted or removed instantly by hand, without damage to the head or handle. No wedge is necessary, and neither shrinkage nor swelling can loosen the head.

The standard faces are constructed of medium-grade " P " plastic, of cylindrical shape, and fit flush with the head. The faces can be instantly replaced by hand, when required. Alternative faces of softer or harder plastics, of compressed hardwood, and of rubber will shortly be available. These will be of the standard cylindrical shape, and also in dome, cone, and wedge shapes, thus enabling the one hammer to be used with a wide variety of faces, to suit most hammering purposes on all metals and many other materials. These new hammers are made in four diameters, i.e., 1½, 2, 2½, and 3 in., with weights approximately the same as boxwood mallets of similar size.

IMPROVED GUN FOR STUD-WELDING PROCESS

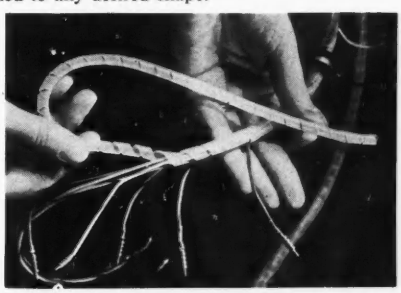
A new and improved type of gun for their stud-welding process is announced by Philips Electrical Limited, of London, W.C.2. Although the basic process is unaltered, the actual gun has been completely redesigned and incorporates several new features. Thus, the barrel is now hollow, so that the reverse end of studs can be accommodated inside the gun. This arrangement permits the use of ¼, $\frac{5}{16}$, ⅜, or ½ in. mild-steel studs up to a maximum length of 8 in. with the standard support leg.

Special studs are not required—any normal plain or threaded type is satisfactory—and standard, mild-steel wire nails, split pins, wood-screws, and countersunk and cheese-headed B.A. screws can also be welded. A high degree of accuracy in placing studs is possible, since the support leg is fitted with a positioning foot, the edges of which are bevelled so that the hairline register-marks can be perfectly aligned with centre-lines scribed on the workpiece. When the gun is loaded, the amount by which the stud projects beyond the plane of the support-leg tips affects the quality of welds. To permit ultra-fine control of this distance, therefore, the gun is now fitted with a vernier adjustment. Another added refinement consists of three different spring tensions to alter the pressure with which the stud is forced into the weld pool. These can be varied to suit overhead, vertical, or downhand operation.

Like its predecessor, this new gun has the great advantage of being suitable for operation from any standard a.c. arc-welding transformer, giving a minimum of 70 V open circuit. Special plant is not necessary.

SPIRALLY CUT PLASTIC CABLE WRAPPING

A new and extremely simple form of cable wrapping, designated " Spirap ", has just been introduced by the Computer Control Company, Inc., of Wellesley, Mass. The spirally cut tubing of insulating plastic, as shown in the illustration, is quickly wrapped around wire bundles up to 2 in. in diameter, while individual wires are easily led out or entered through the spiral cut, the leads being formed into a cable which is firm but which can be formed to any desired shape.



Tedious cable lacing is completely eliminated, and electrical conductors are protected from wear and abrasion over the entire cable length. The sheath also provides excellent electrical insulation from metal chassis, and cables with the new covering, can be secured to chassis with conventional cable clamps, which no longer touch the critical conductors themselves. Furthermore, changes in cabling can be made easily. The plastic wrapping is quickly unwound to permit wires to be added, taken out, or relocated. Because of the speed of application, hours can be eliminated from many cabling operations. A single size of " Spirap ", with an initial diameter of ¼ in., can serve nearly all cabling needs, eliminating the need for stocking several sizes of sleeving and binding twine. A firm and protective covering is ensured, even though the size of the wire bundle varies greatly over the cable length. The standard material used is polyethylene, but other materials can be furnished to special order.

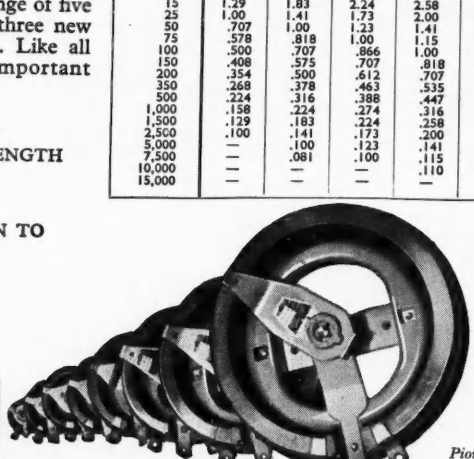
NOW THERE ARE EIGHT!

BERCO
TOROIDAL RHEOSTATS

So popular has the original range of five Berco rheostats become that three new models have been introduced. Like all Bercostats they have five important features:—

- VITREOUS ENAMEL BONDED
- HIGHEST MECHANICAL STRENGTH
- MAXIMUM ELECTRICAL PERFORMANCE
- MINIMUM SIZE IN RELATION TO POWER DISSIPATION
- CAN BE USED IN TROPICAL SITUATIONS WITHOUT MODIFICATION

Ohms ± 10%	CURRENT RATINGS							
	L.25	L.50	L.75	L.100	L.150	L.225	L.300	L.500
1	—	7.07	8.66	10.00	12.50	15.0	17.3	22.3
2	3.54	5.00	6.12	7.07	8.66	10.6	12.2	15.8
3	2.89	4.08	5.00	5.75	7.07	8.66	10.0	12.9
5	2.24	3.16	3.88	4.77	5.48	6.71	7.75	10.0
7.5	1.82	2.56	3.16	3.65	4.47	5.48	6.32	8.17
10	1.58	2.24	2.74	3.16	3.88	4.74	5.48	7.07
15	1.29	1.83	2.24	2.58	3.16	3.87	4.47	5.78
25	1.00	1.41	1.73	2.00	2.45	3.00	3.46	4.47
50	.707	1.00	1.23	1.41	1.73	2.12	2.45	3.16
75	.578	.818	1.00	1.15	1.41	1.73	2.00	2.58
100	.500	.707	.866	1.00	1.23	1.50	1.73	2.23
150	.408	.575	.707	.818	1.00	1.22	1.41	1.82
200	.354	.500	.612	.707	.866	1.06	1.22	1.58
350	.268	.378	.463	.535	.655	.803	.926	1.19
500	.224	.316	.388	.447	.548	.671	.775	1.00
1,000	.158	.224	.274	.316	.388	.474	.548	0.708
1,500	.129	.183	.224	.258	.316	.387	.447	.578
2,500	.100	.141	.173	.200	.245	.300	.346	.448
5,000	—	.100	.123	.141	.173	.213	.245	.315
7,500	—	.081	.100	.115	.141	.173	.200	.258
10,000	—	—	—	.110	.125	—	.173	.224
15,000	—	—	—	—	—	—	—	.163



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THE BRITISH ELECTRIC RESISTANCE CO. LTD.

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'Grams : Vitrohm Enfield

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Fuel costs are placing an increasingly heavy burden on householders and industrialists; this increase cannot be arrested—*it can be dramatically reversed* by the application of J. & B. Mineral Wool insulation which prevents wastage of heat and reduces fuel consumption by amounts ranging up to 80% and even more in certain cases. J. & B. Mineral Wool is prefabricated in many forms for every type of thermal and acoustic correction.

Write to our Advisory Bureau for full particulars and expert advice on special problems of insulation. Our technicians are backed by a tradition of 70 years' experience.

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And at BILLINGHAM-ON-TEES, SOUTH BANK (YORKS), BRISTOL, BURTON-ON-TRENT, LIVERPOOL AND MANCHESTER.

NEWS OF THE MONTH

PERSONAL

Mr. Gerald M. Burnell, M.B.E., has been elected to the Board and has been appointed works director of the Cork Manufacturing Co. Ltd., Langite Works, Chingford, London E.4.

Mr. B. R. Cant, general works manager of the National Gas and Oil Engine Co. Ltd., Ashton-under-Lyne, Lancashire, has been appointed works director, and **Mr. J. Smith,** chief engineer, has been appointed technical director of the company.

Commander D. T. Collumbell, managing director of C.B.R. Engineering Co. Ltd., Salisbury, Southern Rhodesia, has been appointed a member of the newly formed Southern Rhodesia Electricity Council.

Mr. Michael Colston, a director of Charles Colston Ltd., has been appointed acting director of research and development. **Mr. A. R. Northover,** a director of Tallent (Aycliffe) Ltd., Aycliffe, has been appointed, in addition, general manager, with **Mr. C. T. Howard** retaining his present responsibilities as director and general manager. **Mr. H. C. Addis,** a director of Smith-Richards Ltd., a member of the Coulston Group, has been appointed general manager and **Mr. A. Lukins** has been appointed secretary.

Mr. E. J. Cooper, has been appointed production superintendent of A.P.V.-Paramount Ltd., Manor Royal, Crawley, Sussex, in succession to **Mr. L. J. L. Davies,** who has been appointed southern area representative.

Mr. G. Craven, D.S.C., a director of English Steel Export Corporation Ltd., has been appointed a director of English Steel Forge and Engineering Corporation Ltd., responsible for commercial matters. **Mr. C. Muirhead, O.B.E.,** director of English Steel Castings Corporation Ltd. and English Steel Spring Corporation Ltd., and special director of English Steel Corporation Ltd., and **Mr. E. W. Greaves,** London representative for railway materials, have been appointed to the Board of Davis & Lloyd (1955) Ltd.

Mr. C. K. Curtis has been appointed sales manager of Eagle Engineering Co. Ltd., Warwick.

Mr. Gilbert F. Davies has been elected deputy chairman of Hick, Hargreaves & Co. Ltd., Bolton. **Mr. J. Aspinall** has been appointed deputy managing director. **Mr. Davies** will continue to act as London director. **Mr. J. L. Leyland,** secretary and commercial manager, **Mr. J. J. Warburton,** sales manager, and **Mr. V. Barnett,** technical representative, have been appointed special directors. **Mr. T. Nutall** has been appointed works manager.

Mr. J. T. W. Dewar, A.M.I.Mech.E., M.I.Prod.E., deputy managing director of Firth-Vickers Stainless Steels Ltd. and managing director of Shepcote Lane Rolling Mills Ltd., has been appointed an additional director of English Steel Corporation Ltd., River Don Works, Sheffield.

Mr. G. A. Dummett, M.A., A.M.I.Chem.E., manager of the research and development organization of the A.P.V. Company Ltd., Manor Royal, Crawley, Sussex, has been elected to the Board of the company.

Mr. R. V. Ely, M.I.Mech.E., M.I.E.E., has been appointed group research director of Lancashire Dynamo Holdings Ltd. and has relinquished his position as managing director of Foster Transformers Ltd. and Foster Electrical Supplies Ltd., but will remain on the Board of these companies. **Mr. M. H. Hammill,** general manager and director of Foster Transformers Ltd., and **Mr. L. D. Gunnell,** sales director of Foster Electrical Supplies Ltd., will take executive charge of these companies.

Mr. E .T. Gill, B.Sc., F.I.M., has joined the Development and Research Department of The Mond Nickel Co. Ltd., Thames House, Millbank, London S.W.1, as development officer for constructional alloy steels, in succession to **Mr. L. W. Johnson,** who has been appointed assistant manager of the Department.

Mr. J. M. Hallett has been appointed publicity manager of Ferranti Ltd.

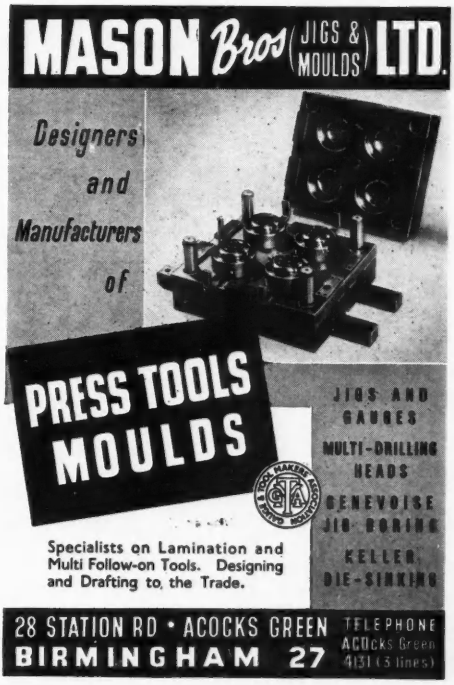
Mr. George J. Hannes has been appointed manager of the Automotive Research and Development Division of the L.O.F. Glass Fibers Company's new Research Center in Waterville, Ohio, U.S.A.

Mr. C. H. Hayter has been appointed works manager (services) of Steel, Peech & Tozer, a branch of The United Steel Companies Ltd., 17 Westbourne Road, Sheffield 10. **Mr. N. H. Bacon** has been appointed superintendent of the Ickles Departments, **Mr. W. Ash,** chief works metallurgist, and **Mr. H. A. Longden,** assistant chief works metallurgist.

Mr. A. F. Hetherington has been appointed chairman of the Southern Gas Board, in succession to **Mr. S. E. Whitehead,** who has resigned for personal reasons.

Mr. H. W. G. Hignett has been appointed assistant managing director of Henry Wiggin & Co. Ltd., Thames House, Millbank, London S.W.1.

Mr. E. P. Holmes, B.Sc., formerly technical director of Conveyancer Fork Trucks Ltd., has been appointed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THE FIRTH-DERIHON STAMPINGS LTD · TINSLEY · SHEFFIELD

executive engineer in charge of design and development of the automotive transmission factory of Borg-Warner Ltd., Letchworth, Herts.

Mr. G. F. Huddleston, Assoc.I.E.E., has been appointed branch manager of the Brighton office of British Insulated Callender's Cables Ltd., 21 Bloomsbury Street, London W.C.1, in succession to **Mr. R. E. Prickett**, who has been appointed London branch manager. **Mr. R. L. Packer**, formerly London branch manager, has been appointed regional manager for the North West Region.

Mr. O. W. Humphreys, director of the General Electric Co. Ltd., in charge of research, has been elected President of the Institute of Physics. **Dr. B. P. Dudding**, has been elected vice-president, **Dr. J. Taylor**, honorary treasurer, and **Professor F. A. Vick**, honorary secretary.

Dr. F. E. Jones, M.B.E., B.Sc., Ph.D., A.M.I.E.E., and **Dr. J. D. Stephenson, B.Sc., M.Sc., Ph.D., M.I.E.E.** have been elected to the Board of Mullard Ltd., Century House, Shaftesbury Avenue, London W.C.2.

Mr. J. R. Y. Johnston, general superintendent for construction, has been appointed managing director of Canadian Pacific Steamships Ltd., City Gate House, Finsbury Square, London E.C.2, in succession to **Mr. A. C. Macdonald**, who has resigned.

Sir Charles Lillicrap, K.C.B., M.B.E., D.Sc.(Eng.), has been elected President of The Institute of Welding. **Mr. J. Strong, M.A.**, a director of British Oxygen Engineering Co. Ltd., has been elected vice-president.

Mr. Andrew McClements, M.I.Mech.E., has been appointed helicopter development manager of Bristol Aircraft Ltd.

Mr. A. W. Morrison has been appointed technical manager in charge of production and development with Expandite Ltd., Chase Road, London N.W.10.

Mr. Herbert Moy, C.B.E., M.I.Mech.E., has been appointed technical director of Warsop Power Tools Ltd.

Sir George H. Nelson, Bt., has relinquished his position as managing director of The English Electric Co. Ltd., and will devote his whole time to his duties as executive chairman of the company. **Mr. H. G. Nelson, M.I.C.E., M.I.Mech.E., M.I.E.E.**, has been appointed managing director.

Mr. E. Oldfield, general sales manager, has been appointed sales director of The New Conveyor Co. Ltd.

Mr. S. Polkinghorn, general sales manager of Compoflex Co. Ltd., 23-25 Northumberland Avenue, London W.C.2, has been appointed general commercial manager with direct responsibility for both home and export sales. **Mr. J. Pickthall** has been appointed sales manager and will be assisted by **Mr. C. V. Hadley** and **Mr. H. J. Bergin**, who have been appointed assistant sales managers. The newly formed export department is to be under the direction of **Mr. A. R. Davies**, and **Mr. R. A. Usher** has been appointed service manager.

Mr. S. L. Poole has been appointed production director of Bowden (Engineers) Ltd., Willesden Junction, London N.W.10.

Mr. R. B. Ransome has been appointed industrial sales manager in charge of fork lift and battery trucks and machine tools of Ransomes, Sims & Jefferies Ltd., Ipswich, with **Mr. C. P. Seager** to assist him. **Mr. J. C. Canning** has been appointed general sales manager of the company.

Mr. R. S. Redmond and **Mrs. M. H. Redmond** have been elected directors of Heyes & Co. Ltd., Wigan. **Mr. Norman F. Brand, A.M.I.E.E.**, and **Mr. W. Talbot** are in charge of production and technical development.

Mr. L. Redshaw, M.Eng., M.I.N.A., M.Inst.W., has been elected to the Board of Vickers-Armstrongs (Shipbuilders) Ltd., Vickers House, Broadway, London S.W.1. He will retain his present position as shipbuilding general manager of the company.

Mr. G. G. Riddick has been elected to the Board of Thomas de La Rue & Co. Ltd., 84 Regent Street, London W.1.

Mr. P. R. Scutt, managing director of Tecalemit Ltd., Plymouth, has been elected chairman of Masson Seeley & Co. Ltd., 14 Howick Place, London S.W.1.

Mr. Douglas L. Standley, formerly personal assistant to the chairman and group managing director of the Teddington Group of Companies, has been appointed assistant to the deputy chairman and managing director of Masson Scott & Co. Ltd., Riverside Road, Summerstown, London S.W.17.

Mr. P. N. Tarleton has joined the Board of the Drewry Car Co. Ltd., 129 Finsbury Pavement, London E.C.2.

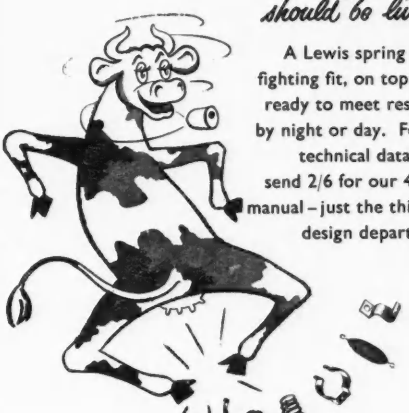
Mr. W. M. Thompson has been appointed sales director of Monsanto Chemicals Ltd., Monsanto House, 10-18 Victoria Street, London S.W.1. **Mr. J. S. Brough** has been appointed general manager of production, **Mr. J. S. Hunter** general manager of development, **Mr. W. E. Hamer** general research manager, **Mr. J. M. Kershaw** chief engineer, **Mr. D. C. M. Salt** general manager of sales, **Mr. G. Dodd** controller of purchases, and **Mr. O. W. Murray** deputy chief engineer. These appointments have been made to meet requirements for large-scale development at Ruabon and Newport and on the company's new site at Fawley, Hants. **Mr. E. L. Pixton** sales controller of Monsanto Chemicals Ltd. and a director of Monsanto Plastics Ltd. will devote the whole of his time to developing the interests of the company in the plastics industry.

Mr. Conrad M. Trost has been appointed consultant and to be in charge of research with the Sturtevant Mill Company, Boston, Mass., U.S.A.

Mr. C. J. Hyde Trutch, M.I.C.E., has been appointed managing director of Victory-Kidder Printing Machine Co. Ltd.

Mr. Harry West has been appointed managing director of A.E.I.—John Thompson Nuclear Energy Co. Ltd.

Springs
should be lively too!



A Lewis spring is always fighting fit, on top of its form, ready to meet resistance by night or day. For lots of technical data you should send 2/6 for our 40-page manual – just the thing for your design department.

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Pyrogas

THE VERSATILE FUEL GAS

FOR CUTTING · HEATING · METAL SPRAYING · ANNEALING · BRAZING · ALUMINIUM WELDING

Pyrogas offers you a concentrated fuel course that can bring notable savings in costs. A standard cylinder, containing 102 lb. of liquified Pyrogas, produces 867 cu. ft. of gas at atmospheric pressure—having a heat value of 2,167,500 B.T.U.s. The reduction in handling time alone may well justify your changing over to Pyrogas.

Other advantages are:

SAFETY. The explosion range of Pyrogas is 2½% to 9½% only. It is non-toxic if accidentally inhaled.

CLEANER CUTTING. Pyrogas produces a square-edged narrow kerf without melting of the upper edges.

LESS SLAG. There is little slag adherence when Pyrogas is used, and that is very easily removed.

NO BACKFIRE. Scale and rust are blown off scrap metal during cutting without any resultant backfiring.

A complete range of cutting and welding equipment is supplied by our associate, RAINVILLE ENGINEERING CO. LTD.

SATURN INDUSTRIAL GASES LTD

Head Office: Gordon Road, Southall, Middlesex

Branches: Birmingham, Manchester, Sheffield, Sunderland, Thornaby-on-Tees, Glasgow, Lymington (Hants).

***SUPER - PYROGAS** has a higher flame intensity than Pyrogas. It is specially formulated for machine cutting.*

Mr. G. A. Whipple, M.A., M.I.E.E., F.Inst.F., chairman and managing director of Hilger & Watts Ltd., 48 Addington Square, London S.E.5, has been elected President of the Scientific Instrument Manufacturers' Association.

Mr. Ernest C. Willis, F.C.I.S., Com.I.E.E., has been appointed by the Minister of Fuel and Power to be deputy chairman of the South Western Electricity Board.

Mr. G. N. F. Wingate has been appointed director and general manager of the Distington Engineering Co. Ltd., in succession to **Mr. A. A. H. Douglas.**

EXHIBITIONS

International Trade Fair, Izmir. August 20 to September 20. (British Chamber of Commerce of Turkey, Piyasa Han 602-606, Asirefendi Cad.11/13, Istanbul, Turkey.)

Trade, Industry and Agriculture Exhibition, Mombasa. August 22 to August 26. (Muslim Association, P.O.B. 583, Mombasa, Kenya.)

National Radio and Television Exhibition, Earls Court, London S.W.5. August 22 to September 1. Preview August 21. (The Radio Industry Council, 59 Russell Square, London W.C.1.)

"Model Engineer" Exhibition, New Horticultural Hall, Greycoat Street, London S.W.1. August 22 to September 1. (The Model Engineer, 19-20 Noel Street, London W.1.)

International Foundry Trades Fair (GIFA), Ausstellungs-Halle, Duesseldorf. September 1 to September 9 in connection with the 23rd International Foundry Congress. (Nordwestdeutsche Ausstellungs-Ges.m.b.H., Ehrenhof 4, Duesseldorf, Germany. Agents: John E. Buck & Co., 47 Brewer Street, London W.1.)

Strasbourg Fair. September 1 to September 16. (Agent: R. C. Liebman, 178 Fleet Street, London E.C.4.)

St. Erik's Fair, Stockholm. September 1 to September 16. (Agents: Thirza West Publicity Ltd., 141 New Bond Street, London W.1.)

Damascus International Fair. September 1 to September 30. (British Overseas Fairs Ltd., 21 Tothill Street, London S.W.1.)

Leipzig International Autumn Fair. September 2 to September 9. (Leipzig Fair Agency in Great Britain, 127 Oxford Street, London W.1.)

Frankfurt International Autumn Fair. September 2 to September 6. (Agents: Lep Transport Ltd., Sunlight Wharf, Upper Thames Street, London E.C.4.)

Flying Display and Exhibition, Farnborough. September 3 to September 9. (Society of British Aircraft Constructors Ltd., 29 King Street, London S.W.1.)

Radio and Television Exhibition, Paris. September 5 to September 15. (Syndicat des Constructeurs d'Appareils Radio Recepteurs et Televiseurs, 23 rue de Lubeck, Paris 16e.)

Levant Trade Fair, Bari. September 7 to September 25. (Italian Chamber of Commerce for Great Britain and the Commonwealth, 652 Grand Buildings, Trafalgar Square, London W.C.2.)

International Ghent Fair, Ghent, Belgium. September 8 to September 23. (Agents: S. R. Tippett & Co. Ltd., 110 Cannon Street, London E.C.4.)

Swiss National Autumn Fair, Lausanne. September 8 to September 23. (Commercial Secretary, Swiss Legation, 18 Montague Place, London W.1.)

Third International Congress and Exhibition for High-Speed Photography, Government Offices, Horse Guards Avenue, London S.W.1. September 10 to September 15. (Congress Secretariat, Department of Scientific and Industrial Research, 5-11 Regent Street, London S.W.1.)

Measurements and Instruments Conference and Exhibition, Stockholm. September 15 to September 23. (Mr. Sven Malström, Box 12035, Stockholm 12, and Anders Beckman Inc., Smalandsgatan 2, Stockholm.)

E.I.A. London Regional Display, Royal Horticultural Hall, Greycoat Street, London S.W.1. October 10 to October 12. (Engineering Industries Association, 9 Seymour Street, London W.1.)

Charleroi Trade Fair, Charleroi, Belgium. October 27 to November 11. (Agent: Mr. Vincent Caers, 67 Rugby Avenue, Wembley, Middlesex.)

Chemical Industry, Rubber and Plastics Exhibition, Parc des Expositions, Porte de Versailles, Paris. November 22 to December 3. (Butler's Advertising Service, 22 St. Giles High Street, London W.C.2.)

PENSIONS FOR PROFESSIONAL ENGINEERS

A scheme to provide continuous pension cover for a professional engineer throughout his career, whatever changes of employment take place, is to be launched in the autumn by the Engineers' Guild.

The Engineers' Guild said: "Long before the concessions were announced in the April Budget, the Guild had been preparing a scheme of group insurance for pensions, suitable for and advantageous to professional engineers, whether self-employed or not. Following the Budget it has been necessary to delay launching this scheme for a short period to ensure that full advantage is taken of the proposals made by the Chancellor of the Exchequer.

"Professional engineers are advised to await the launching of this scheme, which will contain special benefits for them, before deciding upon any of the new policies that are beginning to emerge as a result of the Budget proposals.

"The scheme will be open to all Members of the Guild and to other Members of the Institutions of Civil, of Mechanical, and of Electrical Engineers, who are eligible to become Members of the Guild."

The new ZH OIL BURNERS

Results achieved by the Nu-way ZH Burners are exceptional. Greater combustion efficiency—maximum reliability. Routine servicing can be carried out by non-technical staff. Three models of from 615,000 B.T.U.s/hr. to 2,140,000 B.T.U.s/hr. Write for literature.

- Nu-way combustion head
- Less refractory required
- Visible flame front
- Constant oil temperature
- Two-stage filtration
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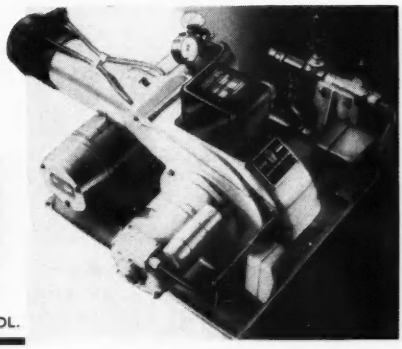

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MAZDA announce that the price of 8 ft. (125-watt) fluorescent lamps (*Warm White* and *Natural*) has been reduced from 32/6 to 25/-. There is no Purchase Tax on these lamps.

At the same time, Mazda Universal Lighting Trunking has been adapted so that 8 ft. tubes can now be mounted anywhere along the trunking run, or in conjunction with 5 ft. tubes. A special 8 ft. open-ended reflector has been designed to fit this flexible lighting system, and is available from stock.

If you are planning a large scale installation, why not discuss it first with our lighting engineers? They can give you an estimation of the cost.

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FIRST TONNAGE OXYGEN PLANT IN GREAT BRITAIN

An important inaugural ceremony was held on August 1 at the headquarters of the British Oxygen Company, at Bridgewater House, London, when Major the Rt. Hon. Gwilym Lloyd-George, Home Secretary and Minister for Welsh Affairs, started Britain's first tonnage oxygen plant at Margam, near Swansea, South Wales, by pressing a button.

This plant is the first of five which are being constructed to service individual iron and steel works in many parts of the country. It has a capacity of 100 tons of high-purity oxygen per day and will be followed very shortly by a companion plant at Margam with a capacity of 200 tons per day. The total cost of the initial scheme is estimated at over £3,000,000, of which the complete Margam project will cost £1,000,000.

An unusual feature of the ceremony was the use of a closed-circuit television link, specially provided for the occasion, by means of which those present were able to watch the starting up of the plant and subsequently to make a complete "tour" of the installations.

BUSINESS NOTES

Skinners (Redbridge) Ltd. announce that they have moved into a new and larger factory. Coinciding with this move, the name of the company has been changed to Skinners (Southampton) Ltd. The new address is Skinners (Southampton) Ltd., Millbrook Trading Estate, Southampton. Tel. No.: 71167/8. Mr. A. Black is managing director of the company.

The Gauge and Tool Makers' Association, Standbrook House, 2/5 Old Bond Street, has arranged for a delegation, consisting of directors of member firms, to visit the U.S.A. The delegation will visit prospective buyers in various American cities and will also attend the Exposition and Convention of the American Association of Iron and Steel Engineers in Cleveland from September 25 to 28.

The Association has decided to hold the next Gauge and Tool Exhibition in the National Hall, Olympia, London, in May, 1958.

Runbaken Electrical Products announce that their head office, sales and service departments have been removed into their new building at 45 Oxford Road, Manchester 1.

Imperial Chemical Industries Ltd. has obtained British Treasury sanction to participate in the project of building, in conjunction with the Hercules Powder Company of America, an eleven million dollar plant on a 20-acre site at Louisiana, Missouri, for the manufacture of methyl methacrylate.

British Anzani Engineering Co. Ltd., Hampton Hill, Middlesex, have now delivered to their associate, the Astra Car Company, the first of their four-wheeled runabouts. This vehicle will cost £347 including purchase tax, and it will be the smallest and cheapest four-wheeler in Britain. It has four-wheel independent suspension and a rear-mounted twin-cylinder 322 c.c. engine. Performance claims are a top speed of 55 mph and a cruising speed of 45-50 mph. Fuel consumption is approximately 60 mpg.

Armstrong Siddeley Motors Ltd., Coventry, have concluded a licence agreement with Werkspoor N.V. of Amsterdam, to make and sell their high-speed diesel engines for rail traction and shipping in Great Britain and throughout the British Commonwealth.

The well-known Dutch company of Werkspoor N.V. (founded 1827) have been manufacturing and designing diesel engines since 1902—the year of the beginning of Armstrong Siddeley Motors.

Werkspoor high-speed engines cover a range from 300 to 3000 hp, having from six to twenty cylinders, and weighing about three to thirty tons. They are used all over the world to power railway locomotives and ships. The Netherlands and Argentine State Railways systems have widely adopted them, and it was recently announced that Werkspoor have been entrusted with the design and production of a revolutionary new Trans-Europe Express.

Armstrong Siddeley manufacture their own range of small diesel engines with power outputs from 6 to 33 hp. They are also the manufacturers of the famous Sapphire range of motor cars, as well as prop-jets, turbo-jets and rocket motors for aircraft. They are members of the Hawker Siddeley Group.

Lincoln Electric Co. Ltd., Welwyn Garden City, England, announce that the company was originally incorporated in the United Kingdom in 1935 as a wholly owned subsidiary of The Lincoln Electric Company of Cleveland, Ohio, U.S.A.

In 1947 the American company sold the whole of the share capital of Lincoln Electric Co. Ltd. of England, to members of its Management who had been responsible for the direction of the British company since its inception.

In March, 1955, the entire share capital of the British company was acquired by Guest, Keen & Nettlefolds Ltd., and the Management continues unchanged.

As a result of these transactions Lincoln Electric Co. Ltd. have ceased for some time to be associated with the original American interests who sold out in 1947.

Lincoln Electric Co. Ltd., of Welwyn Garden City, England, wish it to be known that in addition to the present range of Electric Arc Welding products manufactured, the greatly increased Research Division to be housed in the new Lincoln factory nearing completion at Welwyn Garden City, is now providing to industry many new developments in Manual and Automatic Arc Welding.

British Oxygen Gases Ltd. announce that the capacity of their works at Brinsworth, Yorkshire, is being increased by the addition of a second large liquid oxygen plant.

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A complete range of Drafting Machines for Boards up to 50 feet long, both vertical and horizontal.
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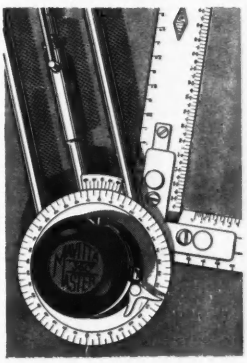

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6M/901

The new plant, due to come shortly into operation, includes the largest liquid oxygen storage tank in the country.

Garnett College, one of the three national colleges training full-time teachers of technical subjects has still vacancies for engineers in the course starting next September. Recognized students pay no fees and may receive maintenance grants. The Principal of Garnett College, 83 New Kent Road, London, S.E.1, will be glad to give details of the College and the courses it offers.

The Machine Tool Trades Association, Victoria House, Southampton Row, London, W.C.1, announce that the total attendance at the International Machine Tool Exhibition held at Olympia from 22 June to 6 July amounted to 102,316.

Standard Telephones and Cables Ltd., Connaught House, Aldwych, London, W.C.2, have established a regional office, under the management of Mr. A. W. Hedley, at Coronation House, 69/71 Market Street, Manchester 1.

Efco—Edwards Vacuum Metallurgy Ltd., a new company, has been formed jointly by Edwards High Vacuum Ltd., Manor Royal, Crawley, Sussex, and the Electric Furnace Co. Ltd., Queens Road, Weybridge, Surrey. The first products of the new company are a range of vacuum melting and pouring furnaces designed for research and production, as well as standard plant for sintering, brazing, annealing and degassing metals.

Classified Advertisements

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

DAVY AND UNITED ENGINEERING COMPANY LTD.

invite applications for the following vacancies:

1. STRUCTURAL DRAUGHTSMAN for Steelworks Engineering Department for work on the Indian Government project at Durgapur, Nr. Calcutta. Duties include layout and design of new factory buildings. Opportunity will arise for transfer of accepted applicant to site at a later date.
2. MECHANICAL DRAUGHTSMAN for Steelworks Plant for the design and detail of steelworks converter plant employing air and oxygen blowing methods. Experience in Drawing Office of open hearth or converter steelworks or plant manufacturer desirable.
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Excellent working conditions. Contributory Superannuation Scheme. Apply : indicating preference with details of age, experience and qualifications to Personnel Officer, Davy and United Engineering Company Limited, Darnall Works, Sheffield 9.

Senior Designer/Draughtsman required for domestic-appliance development laboratories of Charles Colston Limited, in Kingston Hill area.

Applications invited from fully qualified men with a genuine ability and liking for design work, plus an intimate knowledge of production techniques and conditions. Good salary plus incentive participation. Write fully to :

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Erratum. In the Index to Advertisers and their Advertising Agencies of our last issue Sterling Adv. Ltd. was quoted as Agents for Wickman Ltd. by error. Wickman Ltd. is handling its own advertising and does not employ any Advertising Agency.

CHAPMAN & HALL

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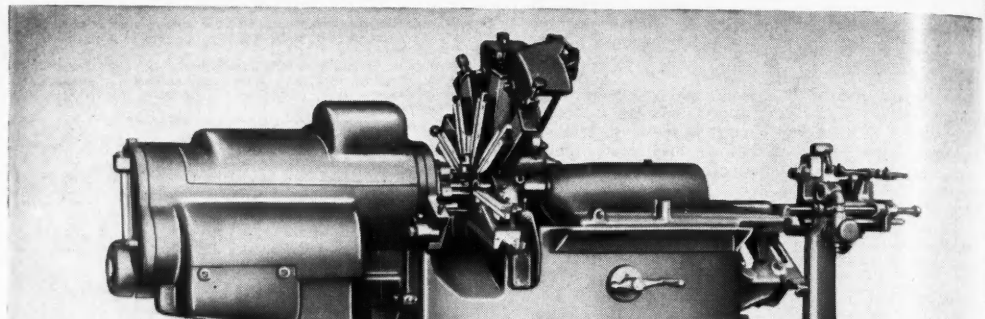

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Newcastle: *Team Valley Trading Estate, Gateshead*
Manchester: *St. Simon Street, Salford, 3*

BOOKS RECEIVED

Practical Solution of Torsional Vibration Problems. (*Vol.* 1 : *Frequency Calculations*). 3rd Edition. By W. Ker Wilson, D.Sc., Ph.D., M.Sc., Wh. Ex., M.I.Mech.E. 736 pp., 144 illustrations. Publishers : Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 105/–.

Based on many years of experience both in research and development of internal combustion engines in the low-, medium-, and high-speed fields, Dr. Ker Wilson's book has long been recognized as a standard text and reference work. As the study of torsional vibration has now gained considerably from improvements in instrumentation and experimental procedures, resulting in a better understanding of some of the more complex aspects of the subject, this third edition, therefore, has been completely rewritten, to bring the subject matter up to date, whilst retaining the original purpose of providing an adequately comprehensive treatment in a form suitable for everyday reference.

The complete work remains in two volumes, but the text has been re-arranged so that each volume is now self-contained in the sense that each deals with a particular aspect of the subject. Frequency calculations and analyses of the characteristics of different types of oscillating systems are included in Vol. 1, which contains considerable additions, particularly in the sections dealing with geared systems and systems containing distributed masses. The effective inertia method for determining natural frequencies is discussed in greater detail, and there is a more comprehensive treatment of the application of this method in cases of coupled vibration. The subject matter has been subdivided into a greater number of chapters for easier reference, and the new edition is introduced by a survey of the history of the subject. Furthermore, the mathematical treatment is simple but adequate, and there is an abundance of fully worked numerical examples from current engineering applications.

Examples in Mechanical Vibrations. By John Hannah, B.Sc.(Eng.), A.M.I.Mech.E., and R. C. Stephens, M.Sc.(Eng.), A.M.I.Mech.E. 160 pp., 98 illustrations. Publishers : Edward Arnold (Publishers) Ltd., 41 Maddox Street, London, W.1. Price : 18/–.

The study of vibrations has become increasingly important in recent years, and this has been reflected by a large increase in the number and range of vibration problems set in the Theory of Machines papers of the universities and professional institutions. This book has therefore been written to supplement textbooks on the theory of machines in this branch of the subject and covers the syllabuses of mechanical vibrations for most examining bodies. In this connection, all the important types of questions set in examinations are covered, including a number which involve theories not generally available to students. Each chapter conveniently consists of a review of the subject matter, together with the derivation of the formulae used, and a large number of worked and unworked examples.

In the worked examples, the aim has been, as far as possible, to obtain the solution from first principles, although in certain types of questions the use of standard formulae and empirical relationships is unavoidable. It is assumed that the student has a reasonable knowledge of the theory of machines, the strength of materials, and differential equations, but, where necessary, references are given to standard textbooks on these subjects.

Engineering Fluid Mechanics. By Charles Jaeger. Translated from the German by P. O. Wolf. 548 pp., 304 illustrations. Publishers : Blackie & Son Limited, 17 Stanhope Street, Glasgow, C.4. Price 60/–.

With the rapid development of the fields covered by hydraulics, ranging from the theory of ideal fluids, fluid mechanics, and aerodynamics to applied hydraulics, it is inevitable that the author of a textbook on this subject must confine himself to certain well-defined limiting aspects. In this book, then, the author covers the methods of analysis and calculation required for the design of water-power schemes, the selection of the material having been based on many years of experience in this type of work.

There are numerous references in this useful and well-translated book intended to give readers some insight into the historical development of hydraulics. Moreover, they point the way to other publications on subjects which naturally cannot be covered fully in a necessarily limited textbook of this type.

Streamlined Specifications Standards (*Vol.* 2 : *Mechanical and Electrical*). By Louis Axelbank, M.E., P.E., and Ben John Small, A.I.A. 505 pages. Publishers : Reinhold Publishing Corporation, New York, and Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price : 80/–.

This second volume in the " Streamlined Specifications Standards " series is a complete guide to the orderly and intelligently organized writing of specifications designed to suit the mechanical and electrical needs of any size or type of building, with the exception of small homes. Subjects appear in logical sequence and are built into a homogeneous structure. Eight major sections cover the various trades, each section being broken down into from six to twenty divisions, according to systems or materials included in the trade ; furthermore, the divisions, in their turn, have numerous subdivisions. The parts are so arranged and numbered that all that is required in practice to make these specifications ready for immediate use is to eliminate any unwanted parts or to substitute special provisions, without disturbing the sequence of the remaining material, except for an occasional change in numbering.

A unique feature of this book is that, like the first volume in the series (" Architectural Building Check List ", by Ben John Small), the specifications are " streamlined ", i.e., they are concise, clear, comprehensive, and easily understood. As such, they will undoubtedly prove of inestimable value to architects, engineers, specification writers, draughtsmen, and contractors.

LATEST INDUSTRIAL LITERATURE

1. Glass Pipelines and Fittings. In an excellently produced and illustrated 28-page catalogue, full details and specifications are given of a comprehensive range of glass pipes and fittings for use in the chemical, food, and allied industries. Made from borosilicate glass of the highest quality, these pipes can be supplied in nominal diameters ranging from ¾ to 6 in. and, depending on size, are suitable for maximum internal working pressures between 25 and 50 psi.

Fittings include U- and Y-pieces, cross-pieces, reducers, hose connectors, couplings, gaskets, sheaths, stopcocks, spacers, make-up joints, pipeline supports, and sink traps.

2. Small Motors and Generators. In a 4-page illustrated brochure, a few examples from a wide range of small motors and generators are described. These items can be manufactured to special requirements, and include ceiling-fan motors, small motors for aircraft use, and miniature permanent-magnet motors for small fans, special mechanisms, and similar lightweight purposes. These miniature motors, for 6, 12, or 28 V, weigh less than 2 oz, have an input of only 2·4 W, operate at 5600 rpm, and are fitted with ball bearings.

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4. Equipment for the Non-destructive Testing of Engineering Materials. Details are contained in a 32-page booklet of two instruments intended for measuring non-destructively certain properties of engineering materials, particularly those of non-homogeneous types, such as concrete, plastics, coals, ceramics, and wood. In certain cases these methods give results which are not obtainable by any other means ; furthermore, these non-destructive tests may be used to replace, or to supplement, conventional destructive methods.

The first of these two instruments is used to measure the time of propagation of a pulse of longitudinal vibrations of ultrasonic frequency through the specimen, a transmitting and receiving transducer being coupled to faces of the material, and waveforms being displayed on a cathode-ray tube, corresponding to the instant of transmission and reception of the pulse. With the second instrument, the resonant frequency of the specimen is measured by mechanically connecting it to a vibrator, the frequency being varied until resonance is reached. The resonant point is shown by a large meter deflection corresponding to the maximum amplitude of vibrations at resonance. From these measurements the dynamic modulus, Poisson's ratio, and the damping coefficient or its reciprocal may be calculated.

5. Link-Type V-Belts. Designed for use in applications where an endless unit is not suitable, owing to structural restrictions or fixed centres, a range of link-type V-belts described in an 8-page illustrated brochure has a number of important advantages. Thus, for instance, a belt of any length can be detached in seconds from a stock coil and can be installed and running in a matter of minutes. Furthermore, they simplify drive design, reduce installation costs, require no mechanical adjustment, take an equal share in the load, eliminating uneven wear, and make it unnecessary to carry large stocks of V-belts of different lengths. In addition, as the construction of these belts allow free air circulation to dissipate the heat caused by internal friction during flexing, internal fatigue is avoided.

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